The Association
of
Engineering and Shipbuilding Draughtsmen.

PUMPING AND FLOODING OF SHIPS.

By E. W. ANSELL.

SESSION 1941-42.

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INTRODUCTION.

It appears that there are very few books or pamphlets dealing with the general subject of pipework in shipbuilding. The following is an attempt (necessarily brief) to set out the general principles and details of fittings, and to give some idea of the methods employed in arranging the various services required for the pumping, flooding and draining of varying types of ships. It is primarily intended for the perusal of junior draughtsmen and others not acquainted with the subject.

All ships are equipped with some apparatus for pumping out bilges, flooding compartments in case of fire, and for draining away water thrown aboard by heavy seas. It is proposed in the following pages to describe the most generally employed methods for attaining these purposes.

PUMPING AND FLOODING.

The pumping system of a ship is not primarily arranged, as is generally thought, to pump water from a compartment that has been holed. Even a relatively small hole in the underwater shell of a ship allows far more water to pass into the ship than can conveniently be dealt with by the size of pump normally fitted aboard that class of ship.

The object of the pump is to clear the bilges of water after the hole has been temporarily patched up, allowing the ship to proceed on an even keel until the proper facilities are available for the necessary repairs. The pumps are also used for clearing bilges of water which is ever present, due to starting planks or leaking rivets, which permit a thin trickle of water to collect in the bilges, making it necessary to pump out same periodically.
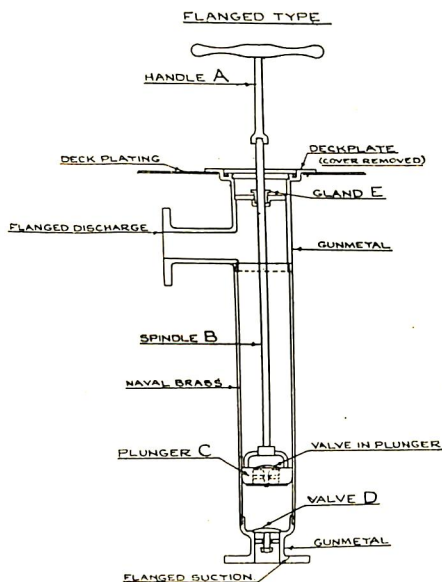
PUMPS.

Bilge pumps are of two general types, power and hand operated. The smaller type of ship, such as small sailing vessels, launches, and the smaller type of coastal vessel, are fitted with hand-operated pumps, while yachts and the larger type of ocean-going vessel have pumps which are power-operated. In general, however, a ship is

usually fitted with a combination of pumps, some power-operated and some operated by hand. Typical arrangements will be described later.

(a) Hand-Operated Pumps.

The pump illustrated in Fig. 1 is known as a "deck hand bilge pump," being fitted with the deck plate and operating handle in a suitable position on the weather deck. Under the deck, the body of the pump is composed of a cylinder containing the plunger and valve of the pump. The bottom of the cylinder is connected by a pipe to the bilges, while immediately under the deck a pipe is taken off the cylinder for discharging the water overboard through the ship's side.

FLANGED TYPE

HANDLE A

DECK PLATING

DECKPLATE (COVER REMOVED)

GLAND E

FLANGED DISCHARGE

GUNMETAL

SPINDLE B

NAVAL BRASS

PLUNGER C

VALVE IN PLUNGER

VALVE D

GUNMETAL

FLANGED SUCTION

Fig. 1—Typical Deck Hand Bilge Pump.

The method of operation is simple. The handle (a) is connected by a spindle (b) to the plunger (c), which is a sliding fit in the sides of the cylinder. As the handle is raised and the plunger lifted, the water is drawn up the pipe through the valve (d) at the bottom of the cylinder. On the downward stroke of the plunger this valve automatically closes, thus imprisoning the bilge water in the cylinder. At the same time, the pressure of the water on the plunger opens a valve at the bottom of the plunger, forcing the water into the upper part of the cylinder. The process is completed

on the upward stroke, when this valve also closes and the water is forced along the discharge pipe overboard. The spindle passes through a gland (*e*), immediately below the deck-plate, the gland being fitted to ensure a watertight joint.

The deck-plate and discharge are formed by a single gunmetal casting, screwed at the bottom to take a naval brass cylinder, which forms the body of the pump. This cylinder is screwed at the base to take a gunmetal casting, which forms a seat for the valve. The plunger and both valves are of gunmetal and the spindle is of naval brass. The deck-plate cover is of gunmetal. In some cases, where the work required of the pump is very light, the valves may be of leather.

This type of hand-pump is used only in the smaller class of ship—launches, patrol boats, sailing yachts, some tugs and similar craft. The pump is usually from 24″ to 30″ in overall length, with a body of 3″ to 4″ diameter, the latter dimension being dependent upon the task for which the pump is required. Being worked by man-power, the capacity of such a pump is naturally limited, depending upon the diameter of the chamber. It is used therefore only for the pumping out of bilge water and similar light duties. Nevertheless, it is a highly satisfactory arrangement for a small vessel to be equipped with three or four of these pumps, each communicating with the bilges of a separate watertight compartment, and having a small power-operated pump in the machinery spaces for dealing with larger quantities of water. Capacities of these pumps vary from about 150 gallons per hour for a pump with 2″ diameter chamber, to about 1000 gallons per hour for one with 6″ diameter chamber. The average sizes of 3″ and 4″ diameter give about 300 and 500 gallons per hour respectively.

(*b*) Semi-Rotary Pumps.

The pump illustrated in Fig. 2 is known as a "semi-rotary" pump. The advantage over the hand bilge pump previously described is that less manual effort is required to operate it, the handle being moved in a semi-rotary manner, describing an arc, as indicated, instead of the far more difficult vertical movement of the previous type. This advantage is offset by the fact that the semi-rotary pump has not the "lift" of the vertical movement type. (The "lift" of a pump being its capacity for forcing water to a height above its normal level). A deck pump is usually more conveniently arranged for operating, as a semi-rotary pump requires a vertical support to which it may be secured.

The semi-rotary pump has a circular casing about 3″ deep, with a flanged inlet and outlet, the first below and the second above the casing or body. A spindle through the centre of the casing is connected to the operating handle at one end, and to the fitting which constitutes the plunger of this pump at the other.

B

OPERATING HANDLE

TYPICAL SEMI - ROTARY HANDPUMP
FLANGED   TYPE.

FLANGED OUTLET

FLAP VALVES C

WING B.

B

SPINDLE

A

A

FLAP VALVE D

STOP A

FLAP VALVE D

PIN

FLANGED INLET

Fig. 2.

This fitting is of gunmetal, shaped as shown, having edges machined to give a sliding fit round the circumference of the casing. In this fitting, or wing as it is called, are two leather flap valves, one on each side of the spindle.   Immediately above the inlet is a small gunmetal casting of an inverted "V" shape, pinned through the back of the cover, with two leather flap valves, one in each arm of the "V."   The cover is of gunmetal.

The method of operation is as follows.   The handle is moved back and forward through the arc of a circle whose size is governed by the position of the two stops A.   This handle is connected to the wing B, which also moves in an arc, pivoting on the spindle, and acting as the plunger which draws water through either of the two flap valves D (according to which side of the wing is in the "up" position).   When this side drops to the "down" position, the valve at D is automatically closed, forcing the water through the flap valve C in the wing.   As this is a non-return valve, the next

"up" stroke forces the water out through the discharge.   This is a double-acting pump, the description above applying to one side of the pump, while the converse is taking place on the other side, *i.e.*, as the water on one side is being forced through the valve C, due to the wing being "down" on that side, water is being drawn through the valve D on the other side, due to that part of the wing being "up."

This pump is met with mainly in sailing vessels and other small craft, for bilge pumping, although on larger craft it is often used for filling fresh water or salt water gravity tanks and other such duties. The diagram shows flanged inlet and outlet, but these can be supplied screwed to take screwed pipe.

The capacity of the semi-rotary pump depends, of course, on the bore of the suction and delivery.   This varies from 4 gallons per minute for $\frac{1}{2}$" bore to 80 gallons per minute for 3" bore inlet and outlet, the size used depending upon the class of ship it is required for.   The medium size of 2" bore gives a delivery of 35 gallons per minute.

(c) Downton Pump.

A very useful pump for medium-sized vessels is the Downton pump illustrated in Fig. 3.   This is a hand-operated pump requiring two to four men to work it, thus giving it a greater capacity than those previously described.   The working principles of this pump are similar to those described before, but in this case the handle and handwheel for operating are connected through the body by a crankshaft, which lifts and lowers the plunger by means of a bow forced up and down between two slides cast one on each side of the barrel.   As before, the inlet valve opens when plunger lifts and water is forced up through the outlet valve to the discharge when the plunger is lowered.

The inlet or suction is usually flanged, but the outlet or discharge can be of various types ; it can be fitted with a hose connection for pumping overboard by hose (this is usually the case when the pump is fitted on the weather deck, and is required only for bilge pumping), or it can be fitted with screwed connection or flanged connection for use when the pump is fitted between decks and a discharge pipe empties through a hole in the shell.   A flanged connection is also used in cases where the discharge is used as a fire-main.

The capacity of these pumps is naturally far in excess of the others so far described, due to the fact that being operated by a number of men a greater force is available for lifting a larger diameter of plunger.   For a $4\frac{1}{2}$" diameter barrel (the lowest size usually manufactured) having $2\frac{1}{2}$" suction and delivery pipes, the capacity is 460 gallons per hour.   For the largest size, with 7"
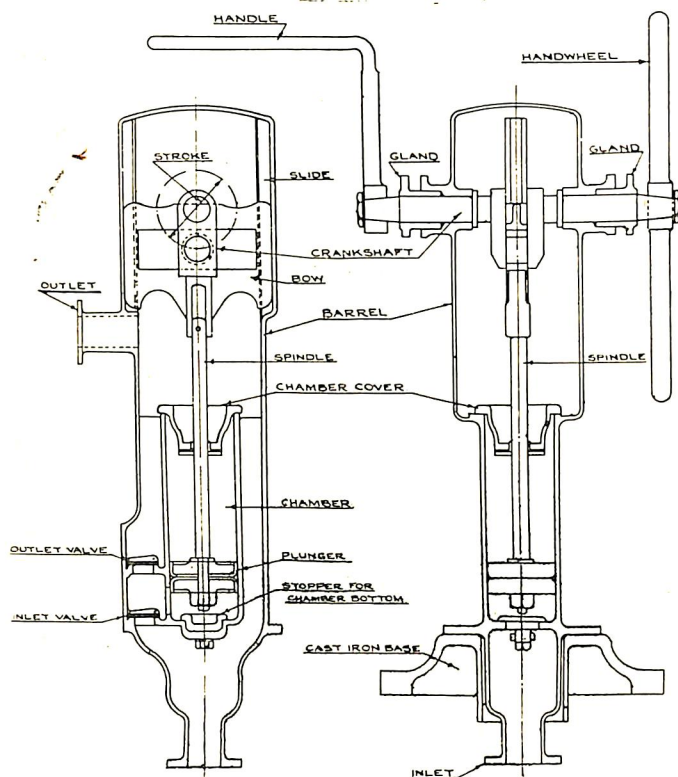
Fig. 3—Typical Downton Pump.

diameter barrel and 4″ suction and delivery, the capacity is 1500 gallons per hour.

This type of pump is usually used in conjunction with a power-operated pump, the Downton pump being fitted for pumping out compartments outside the machinery spaces, while the power pump is arranged in the engine room for pumping out bilges of engine and boiler rooms.

The barrel of the pump is of gunmetal, as also are the crankshaft, bow, pump rod, plunger, glands, valves and chamber cover.

The handwheel and handle are of iron, and the base, for securing the pump to a wooden chock on the deck, is of cast iron.

POWER PUMPS.

For vessels requiring a pump of high capacity, power pumps are the most effective.   These are either steam or electrically driven and are usually situated in one of the machinery spaces.

The underlying principles for working are the same as for other types of pumps, but for anyone wishing a more comprehensive work on this type of pump, its design and application, the very interesting A.E.S.D. pamphlet on "Power Pumps," by C. Edwards, is recommended.

The flooding system, for fire and wash-deck services, is normally worked off the power pump in the machinery spaces, as will be described later.

VALVES.

Having described the various types of pumps most generally met with in shipwork, it is now necessary to study the types of valves used for the efficient control of the pumping and flooding system adopted.

For very low pressure systems the valve itself is usually of leather or fibre, but for most medium and large-sized vessels it is general to use a metal valve on a metal seat, as this will withstand a very heavy pressure of water.

In the types given below and in the following pages, it can be generally assumed that the valve is described as having flanged ends, but if definitely required many of them may be screwed instead and arranged to take screwed pipe in lieu of flanged, but flanging is more generally used.

The Non-Return Valve.

This is perhaps the simplest valve in its operation, and is illustrated in Fig. 4. The body is of gunmetal, in two parts, one being bolted to the other, the body being made thus in two parts so that the top may be readily removed for cleaning purposes, or for repair or replacement of the valve, should this be found necessary.

The top and bottom of the body are both flanged, or screwed to take the pipe in the event of screwed joints being desired. Cast in the lower half of the body and machined to take the valve, is a circular shoulder, or seat, as it is called. Below this is cast a small "lug" to take the spindle of the valve. The valve itself is of gunmetal, circular in shape, being machined to be a good fit on to the valve seat. The valve spindle is dropped through the hole in the "lug" and a nut screwed on the spindle, thus securing the valve.

This is a self-operating valve, the working being extremely simple. Water pumped through the valve body enters from the bottom, forcing the valve off its seat, and escapes through the top. When pumping ceases, the water is prevented from dropping back through the valve body and down the pipe by the valve, which is forced on to its seat by the weight of water pressing on it from above, or by its own weight. This valve is often called a "foot valve,"
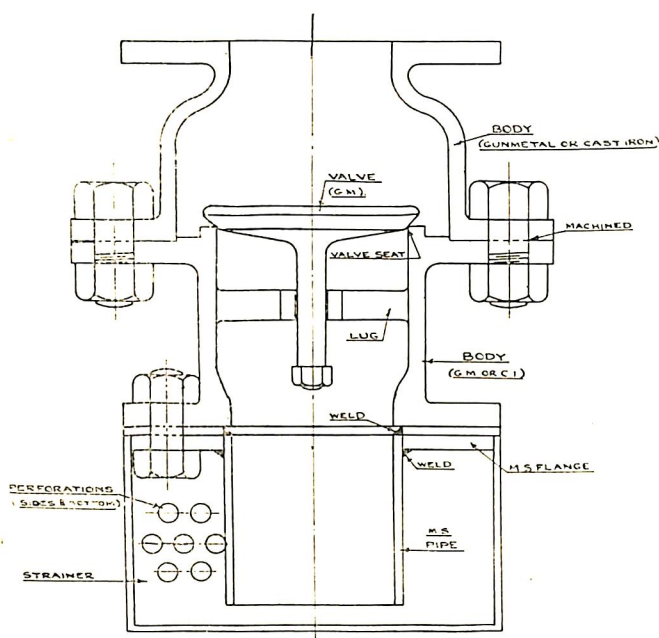
Fig. 4—Flanged Non-Return Valve.

as it is usually fitted at the foot of the suction pipe in the bilges. The valve illustrated is fitted with a galvanised steel strainer for preventing mud or any other extraneous matter from being drawn up the pipe. The strainer is always fitted at the bottom of a suction pipe, whether a non-return valve is fitted or not, and is variously known as a "strainer," "strum box," or "rose box," or "bilge hat." The holes in sides and bottom of the strainer are generally of not more than $\frac{3}{8}''$ diameter, having a combined area of not less than twice the area of the suction pipe.

It will be seen from the sketch of the non-return valve and strainer, Fig. 4, that the top of the strainer is unperforated. The reason for this is that, in the particular case illustrated, the strainer is used in conjunction with another fitting, being composed of a flange, to which has been welded a short length of pipe, the strainer top also being welded to the flange and the whole bolted to the base of the non-return valve.

It may be wondered why this short length of pipe is incorporated, and the explanation is as follows. If the strainer were to be bolted direct to the valve without this pipe, and the level of the water in the bilge compartment served by the valve was at a level just below the top of the strainer, then the pump is sucking

air through the perforations in the strainer, which are above the water level. This naturally drastically impedes the action and efficiency of the pump, making it practically impossible to pump the bilges dry. If, however, this short length of pipe is fitted inside the strainer, leaving no more than half-an-inch between the bottom of the pipe and the bottom of the strainer, the efficiency of the pump is much improved, it being possible to pump water from within half-an-inch of the bottom of the strainer.

The Screw-Down Valve.

This is perhaps the most common of all valves met with in ship plumber work.

The body is globular in shape, with a flange at each end, having a flanged top to take the valve cover (see Fig. 5). The body is of gunmetal and has the valve seating cast and machined in the position shown. The valve is of gunmetal, fitting tightly on the seating, and is secured to a rolled naval brass spindle, which is taken up through the valve cover and gland, having a handwheel fixed on the top. The spindle is screwed into the gunmetal valve cover as shown. The gunmetal gland is secured to the valve cover by means of rolled naval brass studs and nuts, the valve cover being secured to the valve body in the same manner. The gland is fitted to prevent water seeping out through the valve cover at the point where the spindle comes through and is packed where marked with a wad of cotton soaked in tallow, thus making a watertight joint. This "packing" of cotton and tallow is employed in most valves fitted with glands.

Water is drawn (or pumped) along the pipe, entering the valve on the right-hand side. To permit it to pass through the valve, the handwheel is turned, raising the spindle by means of the thread. The spindle then lifts the valve off its seat, by so doing allowing the water a free passage up through the valve seat and out of the valve body by the left-hand side. When the wheel is turned the opposite way, the spindle presses the valve down on to its seat, making a completely watertight joint. The valve is always closed with a right-hand motion, and opened with a left-hand motion of the hand-wheel, unless otherwise specified. In some cases the valve being fitted to a pipeline in some inaccessible part of the ship, it is necessary to gear the spindle to a handwheel some distance from the valve, where it may be more easily operated.

Where a flexible portable hose is required, either for wash-deck purposes or in cases where a permanent pipe would prove an obstruction, one end of the valve is fitted with a hose connection, screwed to the valve body in lieu of a flange. It is necessary to be careful when ordering the valve, however, that the hose connection is specified to be fitted to the correct end. If required on a

suction line, for use with a hose to the bilges, then the hose connection would require to be fitted to the right-hand or suction side of the valve, as it will be seen that if fitted on the left-hand side, water entering would not receive a clear passage through the valve, but would create an eddy by striking the top of the valve, thus impeding the flow.

The opposite is the case when the hose is employed for wash-deck services or fire-main, as the hose connection must be fitted to the discharge or left-hand side of the valve.   As will be seen later, it is still more important that the hose connection be fitted on the correct side of the valve in the case of a screw-down non-return valve.

The screw-down valve is fitted both in pumping and flooding systems (as may be deduced from the foregoing paragraphs) and is used simply as a means of shutting off a branch or portion of the main system.   Thus in a main suction line the branches to the various watertight compartments are usually fitted with a screw-down valve just below the branch from the main line.   This enables all or any of the compartments to be pumped out by opening the screw-down valves of the bilge suctions required.

The body of the valve is sometimes made of cast iron, where a more economical job is required, but gunmetal is recommended for high-pressure systems.   For normal services, pressures up to 250 lbs. per square inch are used in testing the valves.   The valve is usually tested to the specified pressure, both with the valve open and closed.   For a hand-pump system the pressure test is as low as 50 lbs. per square inch and the 250 lbs. test is used for services worked by power pump.

Screw-down valves are very rarely used with a hand-pump, as the power is usually insufficient to pump more than one compartment at a time.   Very occasionally a small bore pipe suction may be fitted to a hand-pump, having two branches, each fitted with a screw-down valve.   This is only the case in very small ships.

Screw-Down Non-Return Valves.

The main difference between this and the ordinary screw-down valve is in the valve itself ; this is illustrated in Fig. 5a.   Whereas in the screw-down valve the foot of the spindle is fitted tightly into the top of the valve, in the screw-down non-return valve the valve is allowed a certain amount of play.   This means that when the valve is closed the foot of the spindle is pressed tightly on to the top of the valve as in Fig. 5, but when opened, the spindle is lifted to the limit allowed by the additional play.   It will be seen that in Fig. 5 the spindle when raised would lift the valve as well, but in Fig. 5a the valve remains on the seat until it is lifted by the force of the water pumped through the valve body.   As soon as pumping
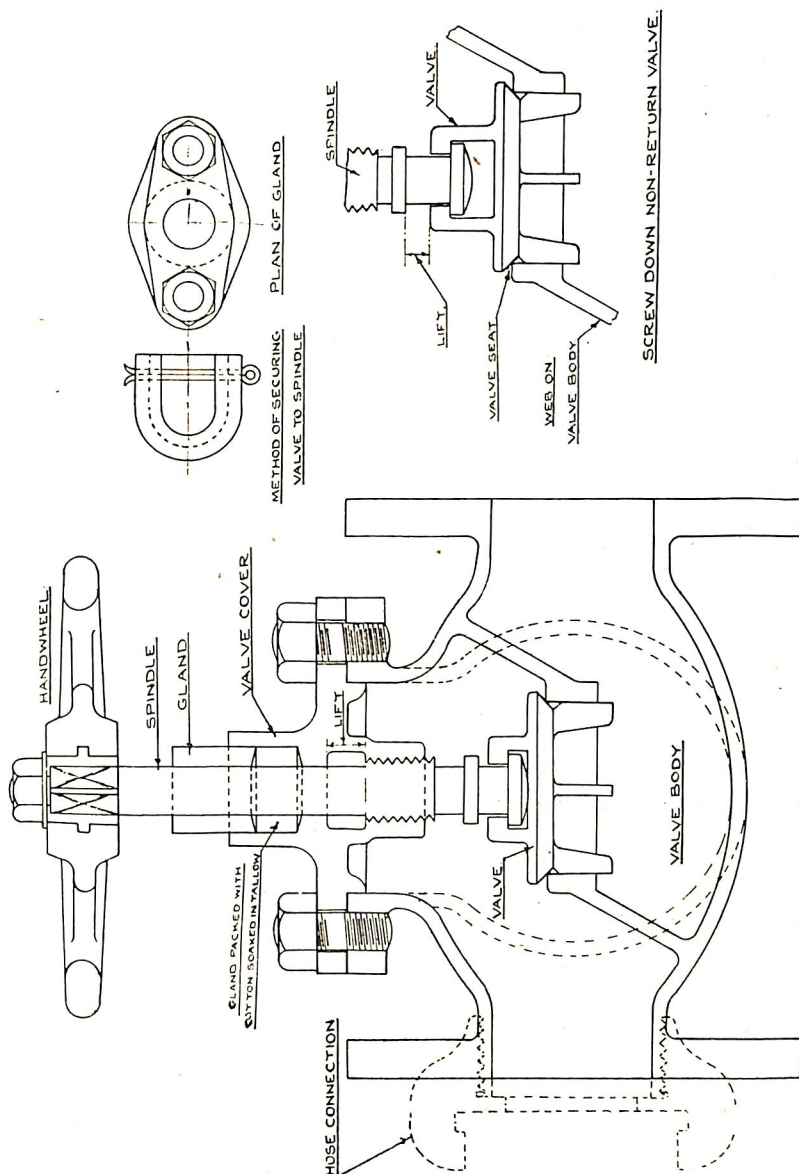
PLAN OF GLAND

SPINDLE

METHOD OF SECURING
VALVE TO SPINDLE

VALVE

LIFT

VALVE SEAT

WEB ON
VALVE BODY

SCREW DOWN NON-RETURN VALVE.

Fig. 5a.

HANDWHEEL

SPINDLE

GLAND

VALVE COVER

LIFT

GLAND PACKED WITH
COTTON SOAKED IN TALLOW

VALVE BODY

VALVE

HOSE CONNECTION

Fig. 5—Typical Screw-Down Valve

C

ceases, water naturally tends to fall back down the pipe through the valve body, but although the spindle is not yet screwed down, the weight of the water forces the valve back on to its seat, automatically closing it.

This type of valve is generally used only in the suction service, and it should be noticed that the valve *must* be fitted in a horizontal position, as if it were fitted vertically the non-return valve would be half open and half closed, and the water dropping back would quite easily pass by the valve and down the pipe, thus ruining the effectiveness of the whole valve. The reason for fitting the screw-down non-return valve to a suction pipe is that when water is drawn from the bilges up to a height of probably twenty feet above, and the pump is stopped, the water left in the pipe is inclined to fall back to the bilges. This would mean that a considerable quantity of water would always remain in the bilges, whereas if a screw-down non-return valve is fitted in the pipe line this difficulty is overcome. Another advantage of this arrangement is that, as there would always be water in the pipe above the valve, the pump would be already "primed" for the next time it is required.

Hose connections are very often fitted on the discharge side of screw-down non-return valves, in cases where a temporary hose would be less of an obstruction than a permanent pipe. It will be seen at once that it is very important when ordering, to state on which side of the valve the hose connection is to be cast. If the valve body is fitted to the suction line the wrong way about, no water will be able to pass through the valve, as it will be pressing on, and not under the valve, thus forcing it tighter upon its seat.

Screw-Down Non-Return and Flood Valve.

This is essentially the same in construction as the screw-down non-return valve, with this difference. In the screw-down non-return valve, when the valve is opened by turning the hand-wheel, a shoulder on the spindle, forcing against the valve cover, limits the rise of the spindle to a distance equal to the lift of the valve when water forces it off its seat. In the screw-down non-return and flood valve, the maximum rise of the spindle is greater, and the valve has three functions. Closed, it is a screw-down valve; when partially opened it is a screw-down non-return valve; and when the spindle is raised to the maximum allowed by the valve cover, the valve is lifted. Therefore, instead of being a non-return valve and being lifted only by the force of the water, the valve may be lifted off its seat by the spindle, when required, thus making it a two-way valve, allowing water to be pumped down a bilge suction pipe instead of being drawn up, in case of, say, a fire in the hold.

`Of course, the pump has to have the necessary cross-connections to enable this to be carried out. That is to say, the suction main has to be arranged so that it may be used in an emergency as a fire-main. This is not a common practice, but the valve has been described for information in the event of such a system being desired.

Sluice or Gate Valves.

(a) Bulkhead Sluice Valve.

. The most common sluice valve met with in shipbuilding is the bulkhead sluice valve, as illustrated in Fig. 6. This is composed of a gunmetal frame riveted or bolted to the lowest part of a
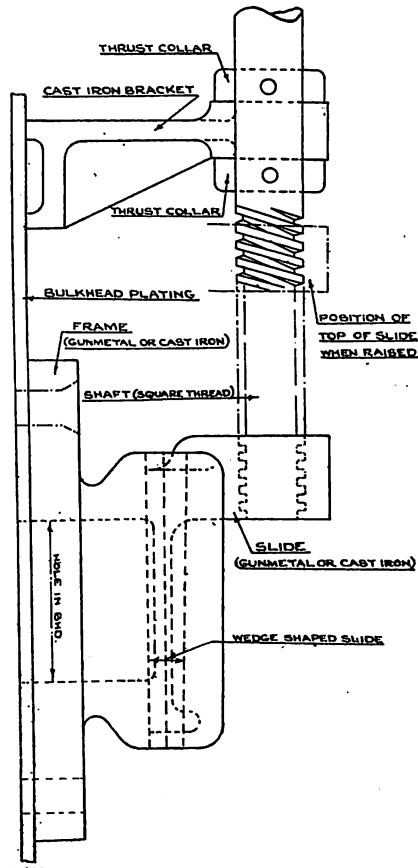
Fig. 6—Typical Bulkhead Sluice Valve.

bulkhead, either longitudinal or transverse, the frame having a wedge-shaped track to accommodate a gunmetal slide, which is also wedge-shaped. This slide has a shaft screwed into the top, which is geared to a deckplate or handwheel in the most convenient operating position.

The shaft is supported by a bracket, as shown, with a thrust collar, usually of gunmetal, pinned through the shaft immediately above and below the bracket.

When closed, the slide is wedged tightly in the frame, thus making the bulkhead completely watertight. When the shafting is turned by means of the handwheel or through the deckplate by means of a key, the lower screwed part naturally lifts the slide up the frame to a position indicated by the dotted lines. This leaves an opening in the bulkhead.

This type of valve is usually fitted in a bulkhead dividing a main watertight compartment with a bilge suction pipe from a secondary watertight compartment not so fitted. Then if bilge water congregates in the secondary compartment, by opening the sluice valve it is admitted into the main compartment, where it can be disposed of by means of the bilge suction pipe through the main suction.

Incidentally, it may be noted that this type of valve is often fitted on a bulkhead between oil fuel tanks, for levelling purposes.

The size of the opening in the bulkhead and of the slide depends on the size of the ship and the purpose for which the valve is required.
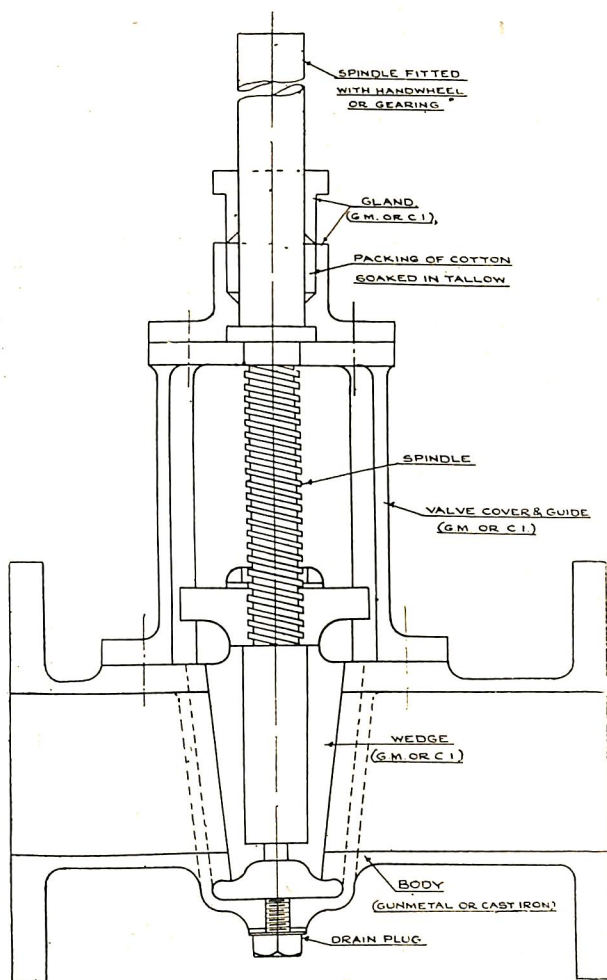
(b) Double-Faced Sluice Valves.

These are sometimes called "wedge-shaped" sluice valves and a typical example is illustrated in Fig. 7.

The body is of gunmetal, cast steel or cast iron, having flanged ends, the centre of the body having a frame on each side to take the slides in the wedge. The wedge is of gunmetal, cast steel or iron and has a spindle screwed into the top and a wing on each side which slides up and down a guide cast on the valve cover. The cover is bolted to the valve body and the gland is bolted to the cover. The spindle passes up through the gland, having a shoulder fitted as shown to prevent it rising. The spindle is fitted either directly or by means of gearing to a deckplate or handwheel. The valve gland is packed with cotton soaked in tallow.

When the handwheel or gearing is turned, the screwed spindle, turning also, and being prevented by the shoulder from rising, causes the wedge to move upwards, thus opening the valve to the passage of water.

This is an ordinary stop valve of the non-rising spindle type. It is often fitted with the wedge normally in the "up" position, i.e., the valve is open to the passage of water. It is fitted in both

SPINDLE FITTED
WITH HANDWHEEL
OR GEARING

GLAND.
(G M. OR C I).

PACKING OF COTTON
SOAKED IN TALLOW

SPINDLE

VALVE COVER & GUIDE
(G M OR C I)

WEDGE
(G M. OR C I)

BODY
(GUNMETAL OR CAST IRON.)

DRAIN PLUG

Fig. 7—Typical Double-Faced Sluice Valve.

suction and fire-main services, and its object is that in the event of the main line becoming broken, damaged or in need of repairs, the double-faced sluice valve fitted nearest to the vulnerable length of pipe is closed, thus cutting off the water supply to this portion while repairs are effected.

There are also sluice valves worked on the same principle having four faces, but these are in general the same as those described. Also there are some with rising spindles, split taper wedges and double disc types, the latter being closed by the spindle forcing a spreader against each of two discs.

VALVE CHESTS.

While we have now dealt with the main types of valves encountered in the pumping and flooding of a ship, there are many variations and modifications of these types. It would obviously be a crude and ungainly arrangement of valves which would require to be fitted in a case where one main line divided at one particular point into three or four branches, each fitted with a valve. To
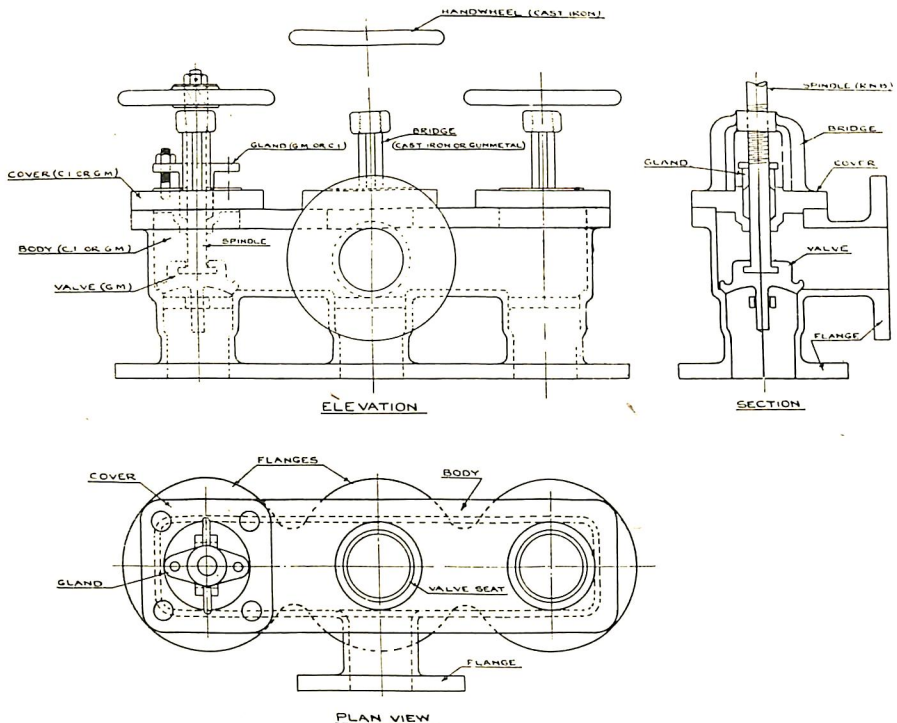
Fig. 8—Typical Valve Chest (Screw-Down Type).

overcome this awkward arrangement, a "valve chest" is fitted, combining all the required valves in one body, thus economising space and making a neater job. Fig. 8 gives a typical example of this type. As in all the foregoing types, the body is most usually made of gunmetal. Gunmetal is the best material for the average pressures of water, up to say 250 lbs. per square inch, which are normally worked to in ship pipework.

As will be seen from the example shown, the inlet of the valve is cast on the side of the body, with three screw-down valves making up the chest, having the outlet flanges on the underside. The construction of each valve is essentially the same as its individual counterpart, with the three handwheels on top of the body, the centre one being fitted higher than the others for ease in operation.

The inlet may be cast anywhere on the sides or end of the body, the position being chosen to facilitate the lead of the inlet pipe to the valve chest without undue bends. The valve chest illustrated is fitted with screw-down valves.

The valve chest may contain either screw-down or screw-down non-return valves, according to the system for which it is designed, and may be composed of two, three, four or even more valves. Sometimes instead of leading three pipes from a three-valve chest, it may be found more convenient to have two outlet pipes and one hose connection, to which is connected a flexible hose when necessary, thus economising space.

In practice the most usual place for a valve chest in suction or fire-main is close to the pump in the machinery spaces, or to the Downton pump if one is fitted. Typical arrangements will be illustrated and described later.

SEA INLET VALVES.

It is obvious that for pumping water through a pipe to various parts of the ship for fire-fighting and wash-deck services, an inlet must be fitted to the ship's side, below the waterline, for drawing water from the sea. Such an inlet valve is illustrated in Fig. 9. The inlet valve is generally of the screw-down type, having valve spindle, gland, etc., of the same design as usual. Occasionally, if the inlet valve is fitted in a reasonably high and accessible place, a handwheel is fitted to the spindle, but as the inlet valve is more often fitted in the bilges near the keel, it is usually the practice to fit gearing to the valve, working it from a handwheel or deckplate in a more accessible position. The actual sea inlet valve is bolted on to a bell-shaped casting open to the sea, having a grating secured in the opening to prevent the access of seaweed, mud, etc., which would foul the pump.

This casting is usually known as a sea tube and is fitted for most medium and large-sized inlet valves. On the smaller type of vessel, however, where weight and materials are to be kept to a
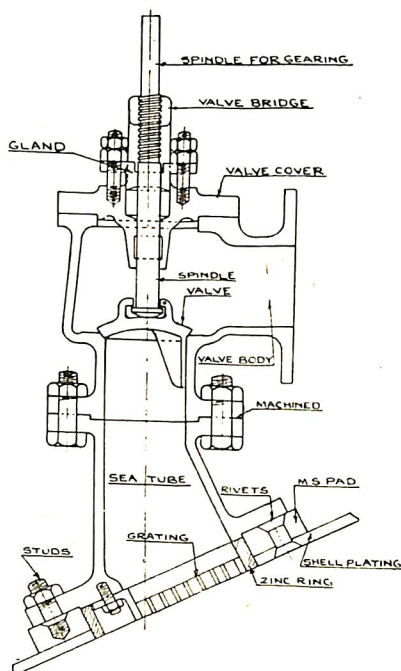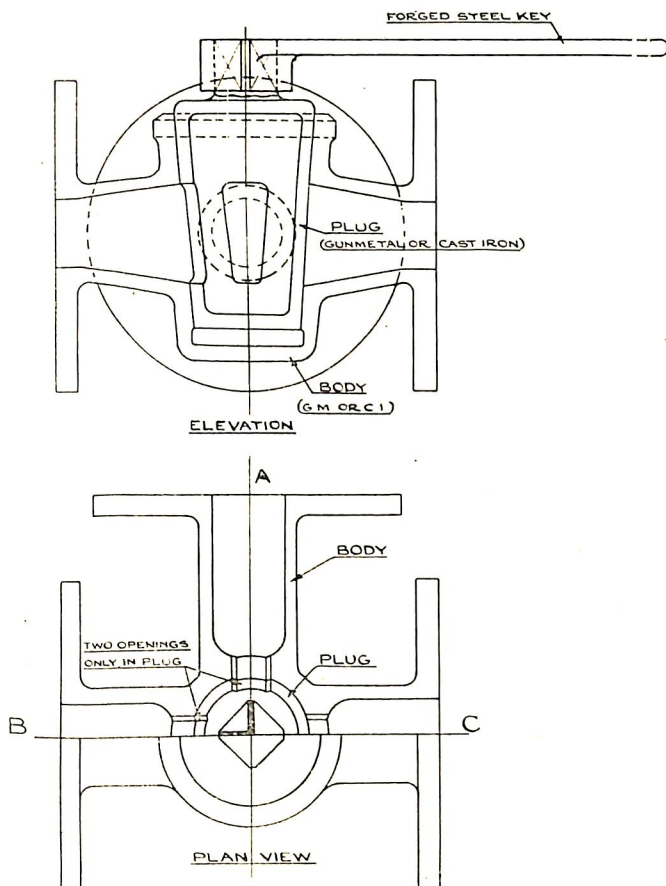
Fig. 9—Typical Sea Inlet Valve.

minimum, the valve is sometimes fitted direct to the shell, having a spigot through the shell and being bolted to a pad or doubling. In the example illustrated, which is fairly typical, the sea tube is bolted to a pad which has been riveted to the shell, the rivets through the pad being spaced between the bolt holes and having countersunk heads filed down to ensure a machine fit between sea tube and pad. The grating (of gunmetal or steel) has three lugs cast on for securing grating by bolts to the sea tube. (Larger gratings have four lugs and smaller ones two.) Gratings should always be fitted with the bars lying fore and aft.

It should here be pointed out that whenever a sea-valve in gunmetal is fitted to a steel hull or on a steel pad, action takes place between the metals, caused by both being in contact with salt water. Unless steps are taken to counteract this, the metals will be eaten away, so it is always the practice to fit zinc rings, either screwed to the pad as shown in the illustration, or fitted flat on the outside of the shell, being secured by taps through the shell.

To return to the inlet valve. This is secured by means of a spigot machined to a close fit into a recess in the top of the sea tube, and having the lower flange of the valve bolted to the top flange of the sea tube.

THREE-WAY VALVES OR COCKS.

When a main pipe is required to branch into two pipes going to different compartments, points or spaces, and water is required to be pumped to or from only one of these points at a time, a three-way valve is fitted, a typical example being given in illustration No. 10. This is sometimes called a three-way cock. The body is fitted with three flanged openings as shown, with a plug machine-fitted into the top. This plug has a square spigot on the top for operating by means of a key. Whereas the body of the valve has three openings, the hollow plug has but two, these being cut at right angles to each other, and not opposite as in the case

FORGED STEEL KEY

PLUG
(GUNMETAL OR CAST IRON)

BODY
(G M OR C I)

ELEVATION

A

BODY

TWO OPENINGS
ONLY IN PLUG

PLUG

B

C

PLAN VIEW

Fig. 10—Typical Three-Way Cock.

D

of an ordinary straight-through plugcock.   On the top of the spigot two lines are engraved at right angles, corresponding to the positions of the openings in the plug.   In operation, if water is required to pass from the main pipe A to the branch pipe B, then the plug is turned by means of the key so that the lines on the key spigot point one to A and one to B.   Then the opening C in the body is cut off owing to there being no opening in the plug at this point.

The same method is employed when it is required to pass water from A to C without allowing any to pass B.   In this case the plug is turned so that the engraved lines are pointing to A and C.

Examples will be shown later in the pamphlet of arrangements using this type of valve.   One point about this type is that it cannot be opened to allow water to flow to both B and C at one time, whereas a valve chest can, if necessary, be so arranged.   The advantage, of course, is that a three-way valve is far more compact, cheaper to manufacture, and takes up less space in the ship than a valve chest.

If it is required to pump water through two outlets simultaneously, a three-way cock may be obtained which will fulfil the conditions, the openings in the plug being arranged so that, when closed, they do not at any point come into contact with the openings in the body.

STEAM BILGE EJECTORS.

Before leaving the subject of valves, it is necessary to describe one more, a combination of a pump and a valve.   This interesting fitting is illustrated in Fig. 11.

The steam bilge ejector has a flange bolted or riveted to a pad on the shell of the ship, usually up to about twenty feet above the keel.   The flange is connected to a right-angled casting as shown, having a parallel discharge through the ship's side, but having a constriction in the vertical branch.   At the top of this vertical pipe is fitted a valve (non-return) with an adjusting screw passing through a gland, for operation outside the ejector.   The bottom of the vertical branch is flanged and to this is bolted a casting having a flanged opening at top, bottom, and on one side.   The bottom flange is bolted to the bilge suction pipe, while the side flange is bolted to the steam inlet.   Inside this casting is a steam nozzle, pointing upwards as shown.   Now, if we open a valve on the steam line and allow steam into the ejector, it is forced through the nozzle and rapidly expands and then contracts as it passes into the wider vertical branch of the ejector, and is forced through the constricted portion A.   The increased velocity of the steam through A causes a suction effect on the bilge pipe, which draws water up from the bilges, running with the steam through the valve B, both being discharged through the outlet C.
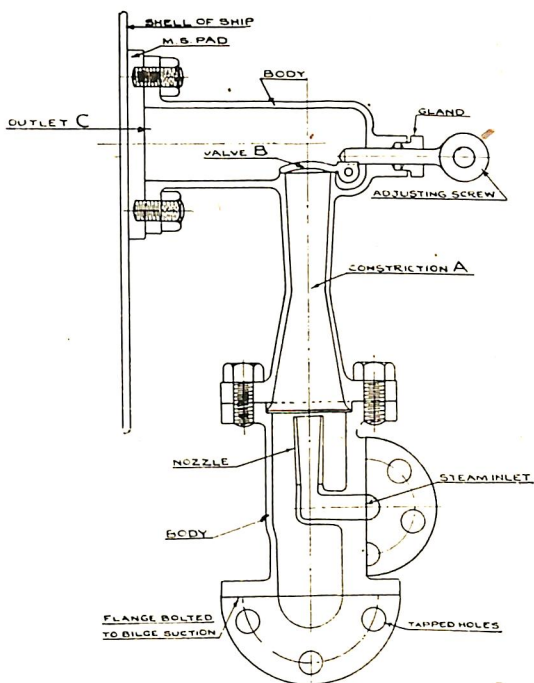
Fig. 11—Typical Steam Bilge Ejector.

For those interested in the theory of this method of suction, the explanation is as follows :—

When the steam is constricted at A, it naturally increases in velocity.   It is a principle of mechanics that the sum of the pressure energy and the kinetic energy is constant, but as the velocity increases the kinetic energy is greater at A.   Therefore the pressure energy must be less.   Now, the pressure at C and in the bilges is that of the atmosphere, therefore the pressure of A is less than this. It is obvious that the water in the bilges will be forced up the pipe by the atmospheric pressure, thus pumping out the bilges.

These steam bilge ejectors are usually fitted in the machinery spaces, as additional bilge suctions, although on occasion they are also fitted outside machinery spaces.   This is unusual, however, as it means a steam line has to be carried through the ship especially to serve the ejectors, whereas, in the machinery spaces, the auxiliary steam range is ready to hand.

The same effect is obtained using a flow of water through a nozzle, instead of steam, but steam is far more efficient, the lifting capacity being greater.   Besides this, it is not always convenient

to run a water system through a suction pipe, as, if the system should develop a fault, the water might possibly drop or seep through the suction pipe, flooding the compartment it is required to pump out.

The capacity of these steam bilge ejectors is naturally dependent on the steam range, but it is quite possible to reach from 20 to 40 tons per hour.

The advantage of this type of "pump" is its limited number of working parts, its compactness, and the fact that no valve chests or bulky fittings are usually required, the whole system being composed of the ejector, steam connection, single pipe to bilges, and a strum box at the end of the pipe.

No claim is made to have described all and every valve met with in shipbuilding, but those described in the preceding pages are those generally met with and universally employed. There are many patent valves and adaptations of those described, but we are concerned in a pamphlet of this size only with typical fittings, those described giving a fair idea of arrangements made to cover most normal requirements. These should serve at any rate to indicate the general method of operation of a pumping system, and as a guide to the understanding of any unusual types which may be encountered.

There are also many standard designs, differing in one respect or another from those described, but only a general description is intended and the valves as described have their counterparts in the catalogues of any well-known valve maker. It is intended merely to show the method of construction and operation of the standard types, and for what purpose they are used, so that the young draughtsman may order from the catalogues, with due under-standing of the purposes for which he requires his valves.

DECKPLATES, SOUNDING, Etc.

Deckplates are used for a variety of purposes on shipboard and there is an infinite variety of types, but in general a deck-plate is used either for operating a valve or fitting from a distance, or for filling or sounding a tank or similar space from a distance.

In the former case the advantage of the deckplate over the handwheel for operating gearing to a valve is that a deckplate may be fitted in an open space on the deck, whereas a handwheel would create an obstacle, protruding as it does some 30″ above the deck. It is thus possible to fit a deckplate in the most direct line possible from the valve, but a handwheel is usually fitted against a bulkhead or casing side, where it will prove no obstacle.

For filling or sounding, unless there is a filling funnel or a sounding pipe fitted above the deck, which once again creates an obstacle in an open space, a deckplate is the only practicable fitting.

It should be pointed out, however, that where possible a hand-wheel should be fitted in the interests of economy, provided always that the saving in cost of a handwheel against that of a deckplate is not nullified by an increase in the number of gear wheels, universal joints, etc., made necessary by the extension of the gearing to a suitable handwheel position.

Again, in the case of a sounding tube, if it is possible to run the sounding tube against a bulkhead or similar structure, this should be done. A sounding pipe carried some 2 ft. above the deck and fitted on the top with a locked cap presents a great saving in cost over a deckplate, which is a casting and usually requires a costly pattern to be made before being cast.

However, where the arrangement definitely calls for a deck-plate in spite of the extra cost involved, two typical examples are given for guidance, Figs. 12 and 13.

The example given in Fig. 12 is used for gearing to a valve with a lift spindle, such as the sea inlet valve (Fig. 9). It may also be fitted to any type of valve with a lift spindle, which is situated immediately under the deck.
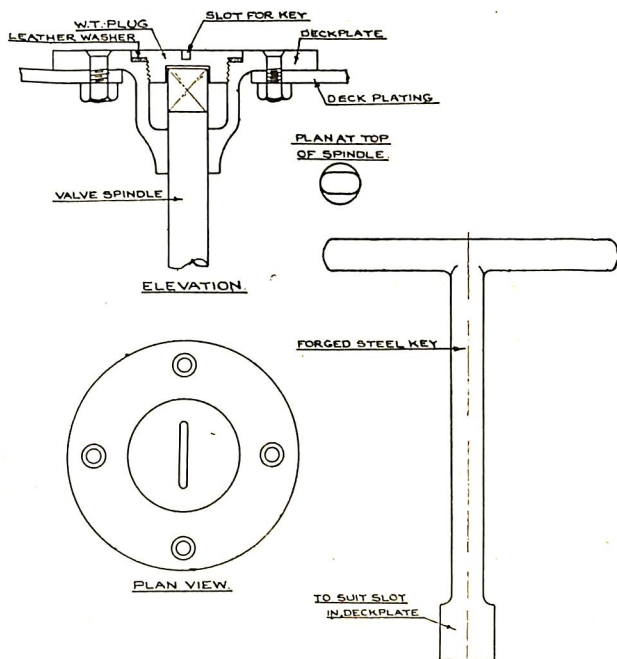
Fig. 12—Typical Valve Deckplate.
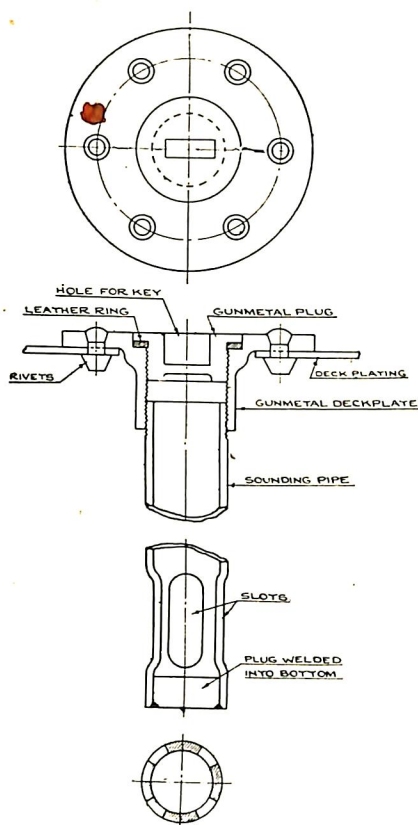
Fig. 13—Typical Sounding Deckplate.

The deckplate is normally entirely of gunmetal, having a flange which is riveted or bolted to the deck, and an appendage below the deck to take the spindle.   Into this flange is screwed a watertight plug, screwing on to a leather washer, thus ensuring a watertight joint.   The plug in the deckplate illustrated has a hole in the underside to take the spindle, thus preventing the spindle turning unless required.   The spindle and plug are so arranged that the plug may only be screwed in tight when the valve is completely closed.   In the top of the plug is a slot to take a forged steel opening key, as illustrated, and the deckplate is so designed that the valve is opened by the spindle being turned the requisite number of times and raised by the action of the plug in unscrewing.

A similar type of deckplate is fitted to a non-rising spindle, the only difference being that a valve with this type of spindle cannot be opened by unscrewing the plug in the deckplate.   The

plug is not, therefore, usually hollowed out to take the spindle, but is fitted with a slight clearance between the bottom of the plug and the spindle. In this case a further forged steel key is required for operating the spindle when the plug is removed. In the event of the deck plating being rather thin in way of the deckplate, a doubling plate is often fitted as additional stiffening.

The deckplate, illustrated in Fig. 13, is a typical example of the sounding deckplate. The general arrangement is similar to that previously explained, except that the sounding tube is screwed into the bottom of the deckplate, instead of the spindle passing up through it. The plug is screwed on to a leather ring as before, and has a slot in the top for unscrewing by means of a key, as illustrated in Fig. 12.

The sounding tube continues down to the bilges of the compartment concerned and sometimes has a plug welded to the bottom (Fig. 13). In this case, slots are usually cut in the pipe, as shown, as close to the plug as possible.

When sounding, the sounding rod (which is of steel), or the sounding tape (which has a weight on the end of a flexible steel tape), is dropped through the hole in the deckplate. The weight or heavy rod strikes the plug at the bottom, preventing any damage to the shell plating which would result were the plug not fitted, and the weight just dropped on to the bare steel. The slots, of course, are for letting the water or other liquid into the pipe.

Sometimes, instead of a plug being fitted in the bottom of the sounding pipe, the pipe is run to within about an inch of the bottom of the compartment and a pad is riveted or welded to the shell immediately beneath it, leaving just sufficient room for the water to enter the pipe. Here again the pad takes the continual wear due to the dropping of the weight or rod.

Sounding tubes are fitted in most bilge compartments, in fresh-water and oil-fuel tanks, feed tanks, etc.

Where a deckplate is required for filling purposes, such as oil-fuel filling, fresh-water filling, etc., it is similar to that illustrated in Fig. 13, except that as a rule the pipe is not screwed into the deckplate, but the bottom of the deckplate is flanged, being bolted to a flange on the filling pipe. In low-pressure systems only is screwing permissible for filling pipes.

On some occasions it may be found necessary to lock a deckplate to prevent unauthorised opening. This may be done in various ways, the simplest being to fasten a strip through a slot in a lug welded to the deck close to the deckplate, across the key slot in the plug, to a lug on the opposite side of the deckplate, where it is flanged up for about an inch, a hole being drilled through the flange and the lug to take a padlock. More complicated locking arrangements are sometimes fitted, being composed of a special padlock fitted in the deckplate, underneath the plug, so that the

valve spindle may not be turned without the padlock being removed. These are special requirements, however, and it is not proposed to go into any further detail.

In some arrangements, instead of a flooding pipe being taken from the fire-main to a compartment containing inflammable material, a valve with hose connection is fitted on a short branch from the main and is connected by hose to a hose adaptor screwed into the sounding deckplate. It is thus possible quickly to flood the compartment through the sounding tube, saving the space and cost of an extra flood pipe direct from the fire-main.

The hose adaptor is merely a casting, hollow, with a hose connection at one end and screwed at the other for screwing into the deckplate. When this hose adaptor is fitted to a deckplate, the plug in the deckplate is screwed to the same diameter and number of threads as the screwing on the adaptor. Thus, when the plug is removed, the adaptor may be screwed into the same hole.

HOSE CONNECTIONS.

Many references have been made in the foregoing pages to hose connections. There are several standards in general use, among them being London County Council, Southern Railway, Nunan and Stove and British Admiralty. The type in most general use is, I consider, the screwed type, in which the casting on the end of the hose is screwed into the hose connection making a water-tight joint, but a very popular type is the bayonet joint, perfected by Messrs. Nunan and Stove, I believe.

In this type, the casting on the end of the hose is placed face to face with the hose connection on the valve or pipe, and is locked merely by twisting it. The locking takes place due to the hose casting being wedged tighter as it is turned.

A hose connection may be either cast on the valve or it may be cast on a flange which is bolted to the valve. Hose connections need not necessarily be fitted to a valve at all, much depending on the purpose for which they are required. If they are to be fitted in, for example, a main suction or fire-main where a large amount of water is frequently likely to pass, then they should be fitted to a valve. This is necessary, because although all hose connections are fitted with a cap and chain when not in use, it is possible that the cap may be left off through carelessness, with the result that if there is no valve fitted, the next time the service is used a flood of water is delivered through the hose connection with disastrous results.

If, however, the hose connection is at the end of a filling pipe, for connecting by hose say, for example, to a water boat, then it is not necessary to fit a valve immediately under the hose connection, as if the cap is inadvertently left off, the worst that can happen is for dust, etc., to fall into the pipe.

It is likely that the type of hose connection to be used will be specified, and it is therefore only necessary to obtain a standard drawing of the type required to find full details.

It may be useful for readers to note that in the "bayonet joint" type, a No. 2 size is suitable for a pipe of from $1\frac{1}{2}''$ to $2''$ diameter, while a No. 3 size is suitable for $2\frac{1}{2}''$ to $3''$ diameter pipe. These are the two sizes most generally used on medium-sized ships.

PIPES AND FITTINGS.

Having exhausted most of the valves and castings ordinarily met with in a pumping arrangement, we will now deal with the pipes and fittings which constitute the main line of the system.

Pipes are generally of either of two materials for fire-main and main suction. The most commonly used medium is mild steel tube. For most general purposes these tubes are lap welded, but where required for gearing rods they are of solid-drawn steel. Where weight is an essential factor in the choice of material, solid-drawn copper tubes are used. There are standard sizes used by most manufacturers of both copper and steel tubes, but special bores of tubes can usually be supplied at extra cost. The standard sizes are given in Tables, Nos. 1 and 2, for both copper and lap-welded steel pipes. It should be borne in mind when ordering lap-welded steel piping that the bore referred to in the table is the "nominal bore." That is to say, if $2''$ bore pipe, for example, is ordered, the bore is not exactly $2''$, but is only approximate. The outside diameter of the pipe remains the same, but (in the table of steel pipes, for example) the actual bore of the pipe is dependent upon the gauge or thickness of the pipe required. Once again, taking $2''$ bore pipe as an example, if gas quality pipe is required (this being suitable for low pressures), then the outside diameter is $2\frac{3}{8}''$ and the thickness is 8 gauge. If water quality (suitable for medium pressures) is used, then the outside diameter is still $2\frac{3}{8}''$ but the thickness is increased to 7 gauge, thus decreasing the bore. Finally, if steam quality is used, suitable for high pressures, then the thickness is increased to 6 gauge. All tubes below $2''$ are butt welded.

This working to the outside diameter as standard and constant applies only to lap-welded tubes, solid-drawn tubes of both copper and steel being supplied to the bore actually required and not to outside diameters and thicknesses.

In machinery spaces it is usually the engineer's practice to order his pipes to approximately the length required for each section, taking care that no length exceeds 16-20 feet, which is the normal length supplied by manufacturers. As it is a general rule not to order pipes of less than 6-10 feet in length, some firms order pipe for both inside and outside machinery spaces in standard lengths

of 16-20 feet, allowing sufficient extra lengths for wastage. It is perhaps advisable to specify when ordering that the tube should be suitable for bending, although as a rule this can quite easily be done. In cases where bends are rather sharp, pipe should be ordered one gauge thicker than elsewhere.

Again, the total amount of piping may be scaled from the drawings, 10% added for wastage and the piping ordered thus :—

1000 feet of 2″ bore pipe, 2⅜″ outside diameter, 7 gauge thick, to be supplied in long lengths.

As to pressures, the fire-main and main suction are tested to from 150 to 250 lbs. per square inch as a maximum, and most water quality steel tubes will withstand far greater pressures than these, so it is usually unnecessary to specify a test pressure when ordering, although it should always be stated on the arrangement drawing of the system, and also when ordering valves and castings. Pressures should, however, be given for copper pipes, and some

STANDARD DIMENSIONS OF LIGHT GAUGE COPPER TUBE.

Nominal Bore In Inches.	Outside Diameter In Inches.	Wall Thickness.		Theoretical Weight Pounds per Foot.
		Inches.	S.W.G.	
⅛″	·205	·040	19	·08
¼″	·346	·048	18	·17
⅜″	·471	·048	18	·25
½″	·596	·048	18	·32
¾″	·846	·048	18	·46
1″	1·112	·056	17	·71
1¼″	1·362	·056	17	·88
1½″	1·612	·056	17	1·05
2″	2·128	·064	16	1·60
2½″	2·628	·064	16	1·98
3″	3·144	·072	15	2·68
3½″	3·660	·080	14	3·46
4″	4·184	·092	13	4·55

Table 1.

STANDARD DIMENSIONS OF MILD STEEL TUBES.

Nominal Bore.	Approx. Ext. Dia.	Thickness of Pipe.			Approx. Weight/Foot.		
		Gas.	Water.	Steam.	Gas.	Water.	Steam.
$\frac{1}{8}''$	$^{13}/_{32}''$	S.W.G. 14	S.W.G. 13	S.W.G. 12	LB. 0·278	LB. 0·306	LB. 0·337
$\frac{1}{4}''$	$^{17}/_{32}''$	14	13	12	0·385	0·428	0·472
$\frac{3}{8}''$	$^{11}/_{16}''$	13	13	11	0·582	0·644	0·703
$\frac{1}{2}''$	$^{27}/_{32}''$	12	13	10	0·818	0·896	0·973
$\frac{3}{4}''$	$1^{1}/_{16}''$	11	10	9	1·165	1·268	1·403
$1''$	$1^{11}/_{32}''$	10	9	8	1·653	1·833	2·008
$1\frac{1}{4}''$	$1^{11}/_{16}''$	9	8	7	2·367	2·598	2·827
$1\frac{1}{2}''$	$1^{29}/_{32}''$	8	7	6	2·973	3·237	3·500
$1\frac{3}{4}''$	$2^{5}/_{32}''$	8	7	6	3·406	3·710	4·019
$2''$	$2^{3}/_{8}''$	8	7	6	3·786	4·128	4·473
$2\frac{1}{4}''$	$2^{5}/_{8}''$	7	6	5	4·602	4·980	5·447
$2\frac{1}{2}''$	$3''$	7	6	5	5·338	5·779	6·323
$3''$	$3\frac{1}{2}''$	7	6	5	6·309	6·834	7·483
$3\frac{1}{2}''$	$4''$	7	6	5	7·265	7·873	8·627
$4''$	$4\frac{1}{2}''$	7	6	5	8·253	8·945	9·803
$4\frac{1}{2}''$	$5''$	7	6	5	9·230	10·006	10·969
$5''$	$5\frac{1}{2}''$	7	6	5	10·232	11·091	12·159
$6''$	$6\frac{1}{2}''$	7	6	5	12·305	13·332	14·609
$7''$	$7\frac{1}{2}''$	5	—	$^{1}/_{4}$ in.	—	—	—
$8''$	$8\frac{1}{2}''$	5	—	$^{1}/_{4}$ in.	—	—	—
$9''$	$9\frac{1}{2}''$	5	—	$^{1}/_{4}$ in.	—	—	—
$10''$	$10\frac{1}{2}''$	$\frac{1}{4}$ in.	—	$^{5}/_{16}$ in.	—	—	—
$12''$	$12\frac{1}{2}''$	$\frac{1}{4}$ in.	—	$^{5}/_{16}$ in.	—	—	—

Table 2.

indication of the quality required should be given, as soft copper tube would be of no use whatever.

It should be pointed out that gas quality steel piping is too thin for screwing and should be used only in welded systems.

Steel pipes may be ordered either black or galvanized, but it is waste of time ordering galvanized pipes if they are to be welded, as all the galvanize is burnt off in the vicinity of the weld.   So it is a safe rule to order black pipe for welding and galvanized pipe for screwing.   Pipes for screwing may be ordered with screwed ends if desired.   All bent pipes are to be ordered black.

We now come to the various methods of connecting together the lengths of piping in the systems.

Taking steel pipes first, there are two methods in general use, by means of flanges and by sockets and backnuts.   Two types of flanges are illustrated, items A and B in Fig. 14.

ITEM A
TYPICAL WELDED FLANGE.

ITEM B
TYPICAL SCREWED FLANGE.

ITEM C
BRAZING METAL FLANGE
FOR COPPER PIPE

BOLTS

RIVETS

BHD OR DECK

ITEM D
TYPICAL BULKHEAD & DECK PIECE.

ITEM E
TYPICAL SOCKET & BACKNUT

ITEM F
TYPICAL CONE TYPE COUPLING,
FOR CONNECTING COPPER PIPES

ITEM G   TYPICAL TEE PIECE

ITEM H
TYPICAL ROUND ELBOW
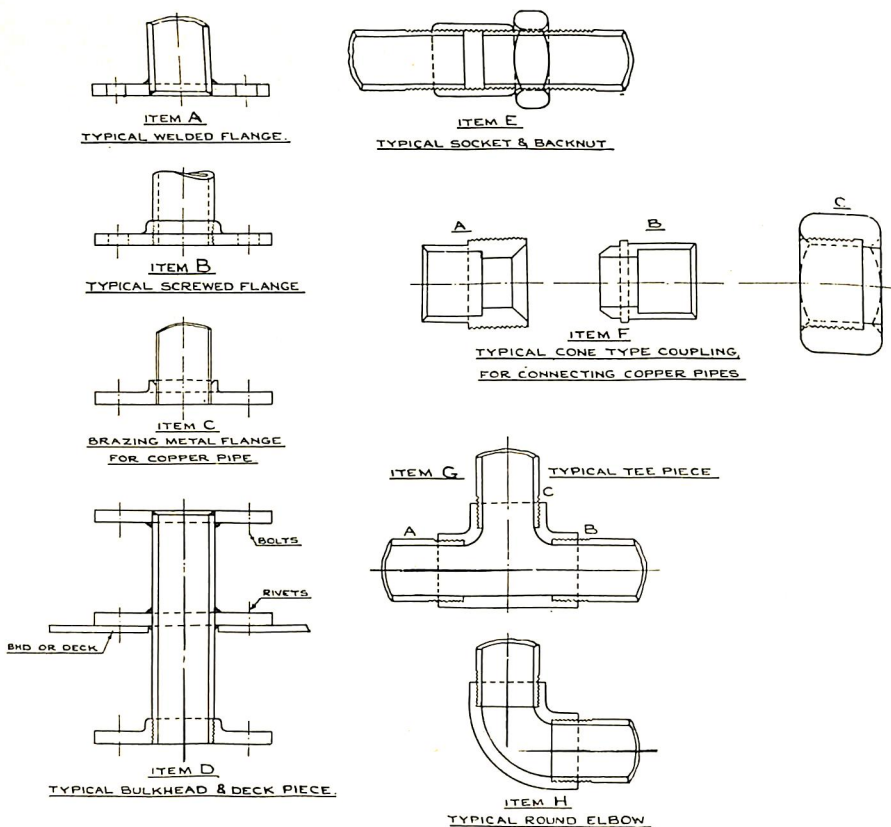
Fig. 14—List of Typical Pipe Fittings.

STANDARD DIMENSIONS OF WROUGHT GAS, WATER AND STEAM FLANGES.

Nominal Bore of Tube.	Dia. of Flange.	Dia. of Boss.	Dia. of Pitch Circle.	GAS AND WATER FLANGES.			STEAM FLANGES.		
				Thickness of Flange.	Total Depth Through Boss.	No. and Size of Bolts.	Thickness of Flange.	Total Depth Through Boss.	No. and Size of Bolts.
$\frac{1}{4}''$	$2\frac{1}{2}''$	$\frac{5}{8}''$	$1\frac{3}{4}''$	$\frac{1}{8}''$	$\frac{3}{8}''$	$4\text{-}\frac{5}{16}''$	$\frac{7}{32}''$	$\frac{15}{32}''$	$4\text{-}\frac{5}{16}''$
$\frac{3}{8}''$	$3''$	$\frac{7}{8}''$	$2\frac{1}{8}''$	$\frac{5}{32}''$	$\frac{7}{16}''$	$4\text{-}\frac{3}{8}''$	$\frac{1}{4}''$	$\frac{17}{32}''$	$4\text{-}\frac{3}{8}''$
$\frac{1}{2}''$	$3\frac{3}{4}''$	$\frac{13}{32}''$	$2\frac{5}{8}''$	$\frac{3}{16}''$	$\frac{9}{16}''$	$4\text{-}\frac{1}{2}''$	$\frac{1}{4}''$	$\frac{5}{8}''$	$4\text{-}\frac{1}{2}''$
$\frac{3}{4}''$	$4''$	$1\frac{7}{16}''$	$2\frac{7}{8}''$	$\frac{3}{16}''$	$\frac{5}{8}''$	$4\text{-}\frac{1}{2}''$	$\frac{1}{4}''$	$\frac{11}{16}''$	$4\text{-}\frac{1}{2}''$
$1''$	$4\frac{1}{2}''$	$1\frac{11}{16}''$	$3\frac{1}{4}''$	$\frac{3}{16}''$	$\frac{5}{8}''$	$4\text{-}\frac{1}{2}''$	$\frac{9}{32}''$	$\frac{23}{32}''$	$4\text{-}\frac{1}{2}''$
$1\frac{1}{4}''$	$4\frac{3}{4}''$	$2\frac{1}{8}''$	$3\frac{7}{16}''$	$\frac{1}{4}''$	$\frac{11}{16}''$	$4\text{-}\frac{1}{2}''$	$\frac{5}{16}''$	$\frac{3}{4}''$	$4\text{-}\frac{1}{2}''$
$1\frac{1}{2}''$	$5\frac{1}{4}''$	$2\frac{1}{2}''$	$3\frac{7}{8}''$	$\frac{1}{4}''$	$\frac{3}{4}''$	$4\text{-}\frac{1}{2}''$	$\frac{11}{32}''$	$\frac{27}{32}''$	$4\text{-}\frac{1}{2}''$
$2''$	$6''$	$3''$	$4\frac{1}{2}''$	$\frac{5}{16}''$	$\frac{13}{16}''$	$4\text{-}\frac{5}{8}''$	$\frac{3}{8}''$	$\frac{7}{8}''$	$4\text{-}\frac{5}{8}''$
$2\frac{1}{2}''$	$6\frac{1}{2}''$	$3\frac{5}{8}''$	$5''$	$\frac{5}{16}''$	$\frac{15}{16}''$	$4\text{-}\frac{5}{8}''$	$\frac{13}{32}''$	$1\frac{1}{32}''$	$4\text{-}\frac{5}{8}''$
$3''$	$7\frac{1}{4}''$	$4\frac{1}{4}''$	$5\frac{3}{4}''$	$\frac{3}{8}''$	$1''$	$4\text{-}\frac{5}{8}''$	$\frac{7}{16}''$	$1\frac{1}{16}''$	$4\text{-}\frac{5}{8}''$
$3\frac{1}{2}''$	$8''$	$4\frac{7}{8}''$	$6\frac{1}{4}''$	$\frac{3}{8}''$	$1\frac{1}{16}''$	$4\text{-}\frac{5}{8}''$	$\frac{15}{32}''$	$1\frac{5}{32}''$	$8\text{-}\frac{5}{8}''$
$4''$	$8\frac{1}{2}''$	$5\frac{1}{2}''$	$7''$	$\frac{3}{8}''$	$1\frac{1}{8}''$	$4\text{-}\frac{5}{8}''$	$\frac{1}{2}''$	$1\frac{1}{4}''$	$8\text{-}\frac{5}{8}''$
$5''$	$10''$	$6\frac{1}{2}''$	$8\frac{1}{4}''$	$\frac{1}{2}''$	$1\frac{1}{4}''$	$8\text{-}\frac{5}{8}''$	$\frac{9}{16}''$	$1\frac{5}{16}''$	$8\text{-}\frac{5}{8}''$
$6''$	$11''$	$7\frac{1}{2}''$	$9\frac{1}{4}''$	$\frac{1}{2}''$	$1\frac{1}{4}''$	$8\text{-}\frac{5}{8}''$	$\frac{11}{16}''$	$1\frac{7}{16}''$	$8\text{-}\frac{3}{4}''$

Table 3.

Item A is a welded flange cut from mild steel plate or stamped out, being a perfectly flat disc welded direct to the pipe. With flanges, as with other fittings mentioned, there are numerous standard tables available giving overall diameters, pitch circle diameters of bolts, size and number of bolts and thickness of flanges. One such table is given on page 33, but flange sizes shown may be modified at the discretion of the draughtsman to suit individual circumstances, providing the bolts and bolt heads will clear the pipes when the flanges are bolted together.

It should be noted that the table given refers primarily to type B, as a column is given for both the diameter of the boss and the total depth through the boss. The other dimensions, however, apply equally well to type A flanges. Type B flanges are of mild steel, with a boss, for screwing to the pipe instead of welding. Another type similar to type B is also in frequent use, but although this has a boss, it is welded instead of screwed to the pipe. Flanges for piping in oil fuel systems are of a heavier type altogether, but as oil fuel arrangements are not included in this work, it is not proposed to go into details. The face of the flange is machined to present a perfectly flat surface, and it is often the practice to machine the flange in way of the bolt heads. When the two flanges are bolted together some form of jointing is used. There are many patent methods and materials for jointing, which may be used as desired, but rubber insertion is quite frequently used in ordinary water systems. A temporary joint which is quite effective may be made with ordinary brown paper coated with linseed oil.

For connecting a pipe to a valve either flanges or sockets and backnuts may be used according to whether the valve has flanged or screwed ends. It may be noted here that pipe is normally screwed on the outside and not internally, so if the valve is to be screwed to the pipe it will save a socket and backnut at each end if the valve is ordered with female ends, allowing the pipe to be screwed direct to the valve.

For connecting screwed pipes, sockets and backnuts are frequently used, a typical example being Item E in Fig. 14. This is merely a short piece of pipe, screwed female, and a backnut. The backnut and the socket are screwed on to one length of pipe, the other length being screwed into the socket, when the socket is held by screwing the backnut tight against it. This makes a tight joint, especially when the jointing is made by coating the contact surfaces of the fittings with red lead and white lead paint. Sometimes the jointing may be made with fibrous washers. In a fresh-water service, for instance, red or white lead must on no account be used, as either would pollute the water.

These sockets and backnuts are of standard sizes and may be ordered from pipe manufacturers without a sketch, provided that the bore of the pipes for which they are required is clearly stated.

Flanged connections are not generally used for pipes under·
$1\frac{1}{2}''$ or $1\frac{1}{4}''$ bore, unless in special circumstances, screwed connections
being more convenient.

Before going on to describe any further connections for steel
pipes, we will deal with connections for copper pipes.   Flanges
(Item C, Fig. 14) are made of brazing metal for copper pipes, and
have a boss, with a small recess to take the brazing.   Diameters
and sizes, as with steel flanges, are arranged to suit the pressure
to which the system is to be tested.

The fitting which for copper piping corresponds to the socket
and backnut in steel piping is illustrated in Item F, Fig. 14.   This
is known as a cone type coupling, being made up of three separate
items.   On the left is the fitting A, into which is brazed one section
of pipe, and this fitting has a screwed end which is coned internally.
The centre fitting B has its end coned on the outside for fitting into
the previous item.   At the end of the cone is a slight shoulder,
and into the other end is brazed the second of the two sections of
pipe to be joined.   The fitting C on the right is the nut for con-
necting the two fittings, being screwed on to the left-hand one,
holding the middle one in place by screwing up tight on the shoulder.

These are the two connections most generally used for brazing
copper pipes, but in addition to these there are several proprietary
types of fittings.   One of the most up-to-date methods of con-
necting copper pipes is by bronze welding and special fittings may
be obtained from the makers for connections.   An advantage of
bronze welding over brazing is that the weld may be carried out
in any position, but of course a special installation is required for
this method.

Where steel pipes pass through a watertight bulkhead or deck,
a watertight connection must be made to maintain the effectiveness
of the bulkhead.   This connection is called a "bulkhead and deck
fitting," and is illustrated in Item D, Fig. 14.   This particular
type is used only for pipes above about $1\frac{1}{4}''$ bore and is composed
of a short length of steel tube with two welded flanges and one
screwed flange fitted as shown.   The fitting has the screwed end,
minus the flange, pushed through a hole in the bulkhead, this
flange being screwed on afterwards, when the centre flange has
been riveted or bolted to the bulkhead or deck plating.   Flanged
pipes are then bolted to the flanges at either end.

A variation of this type is one in which all three flanges are
welded to the short length of pipe, the middle flange being larger
than the two at the ends.   A hole is then cut in the plating
sufficiently large to pass the end flange, the large middle flange
being bolted or riveted to the plating.

Below $1\frac{1}{4}''$ bore the bulkhead and deck fitting is usually a
screwed connection composed of either a casting or a short length

of tube, with a hexagonal shoulder facing on the bulkhead or deck, with a backnut screwing up tight on the other side. The ends are screwed for connection by means of socket and backnut.

For copper pipes, steel bulkhead and deck pieces should not be used, as corrosion is likely to occur due to the action set up by salt water between the copper and the steel. To overcome this, a gunmetal casting is fitted, of a similar shape to Item D, for pipes above about $1\frac{1}{4}''$ bore, and screwed fittings with ends suitable for brazing as in Item F are fitted for pipes below $1\frac{1}{4}''$ bore.

Item G, Fig. 14, shows the fitting in general use for connecting three steel pipes, and this is known as a "tee piece," the pipes being screwed in. These may be ordered without a sketch, provided the bores of the three pipes are clearly given. The bores should be given in the order marked A, B, and C in the sketch.

If it is required to fit four pipes together, a "cross" or "four-way" piece is fitted. This is similar to the "tee piece," but with four branches instead of three. It is advisable when ordering these to enclose a sketch showing in what order the branches are marked, as if all four branches are a different bore confusion is likely to occur.

Both "tee pieces" and "crosses" are obtainable for copper pipes, the ends being suitable for brazing, or bronze welding, as the case may be.

When fitting tee pieces to flanged valves, or in like circumstances, a casting of either gunmetal or cast iron is used, with flanges to suit those of the valves, instead of the ordinary screwed type.

These cannot be ordered from the tube manufacturers and a special sketch is necessary, stating the thickness of casting, size and diameter of flanges, bores of branches, P.C.D. of bolts, etc.

Item H shows an elbow for screwed steel pipes. The same fitting is obtainable for copper pipes, with ends suitable for brazing or bronze welding. They may be ordered from tube manufacturers, providing the bore of the pipe is clearly stated. All standard sizes are kept in stock.

These elbows are to suit a common bore of pipe and are not supplied to suit pipes of two different bores, unless specially ordered thus, when they are charged at the price of the larger bore.

In special circumstances, where a bend is required immediately under a deck fitting, for example, a flanged casting is required. This once again requires a special sketch.

In addition to the aforementioned fittings various others may be obtained for screwed steel pipes, such as bends, longscrews, etc., all of which are described in most tube manufacturers' catalogues.

Where gunmetal valves are fitted to steel pipes, it is usual to fit a corrosion piece between pipe and valve, to avoid corrosion

due to the action of salt water on the metals.   These may be flat discs of cast iron bolted to valve and pipe flange, or a short length of pipe may be bolted to the valve, this being replaced when it becomes corroded, thus saving a new length of pipe.

When piping systems are assembled in the ship it is, of course, necessary to have some method of supporting the pipes from the adjacent structure.   For this "pipe clips" are used, being usually of mild steel, and of a length and shape to suit the particular circumstances under which they are required to be fitted.   They are generally circular, to take the pipe, with supporting lugs for bolting or riveting to the ship's structure.

Pipe clips may be ordered standard size from tube manufacturers, or made to place in the shipyard, the former being the easier and cheaper method.   If they are not long enough as ordered, it is simple to fit a plate extension bracket, whereas making each clip to place is a tedious and expensive business.

PIPE ARRANGEMENTS.

We are now far enough advanced to be able to follow some typical arrangements for the pumping and flooding of various types of ships.   Before describing the arrangements illustrated, it will be advisable to decide what, when designing a pipe arrangement, is the best method of marking the various leads.

There are two ways of describing the system in general use. The first is to give each pipe and fitting on the drawing an index letter or number, and then to draw up a table at the end of the drawing describing the purpose, size, etc., of each such pipe and fitting.

One column is needed for the index letter or number, another for the number off each, a wide column for the description, one for size, and a final column for remarks.

The second method is for each pipe and fitting to be marked on the drawing with a small descriptive note as to its size and purpose.

Most firms adopt one of these methods or a similar method for describing the system on the drawing, so it is a simple matter to follow the practice of previous arrangements done by a particular firm.

When the arrangement is completed, all the order forms, detail drawings, etc., are made up from the information supplied on this drawing.

It is a common practice to draw main suction and fire-main pipes in distinctive colours on the arrangement to avoid confusion, the colours being either to specification, where they are sometimes stated, or to the general practice of the firm concerned.

The illustration, No. 15, gives the general hold plan of a small passenger and cargo steamer.   When drawing a piping arrangement, it is, of course, necessary to give plans of each deck, profile and sections, in full detail, but to bring the drawings within the scope of this pamphlet, still keeping them as clear as possible, it has been necessary to give a typical hold plan of some types, and typical elevations of others.   In this way a general idea is given of what is required.

PUMPING ARRANGEMENT FOR A CARGO STEAMER.

It will be seen at a glance from Fig. 15 that many of the pumps shown are cross-connected, one to the other, so that in the event of one pump failing to function, another may take on its work.

Starting with the bilge and ballast pump, which is the one most directly concerning us, it is possible to pump out several compartments, namely :—

The fore peak ;
The ballast tanks port and starboard at the aft end of the engine room ; and
The after ballast tank at the extreme after end of the hold.

This bilge and ballast pump is power-operated.   A 2″ screw-down valve is fitted to the suction pipe from the fore peak, and to that from the after ballast tank, both being arranged close to the pump for ease in operation.   The wing ballast tanks are controlled from a 2″ valve chest situated close to the port tank.   This chest contains two valves, one for operating the suction to each tank.   The suction in each case is 2″ bore, being led to a strum box fitted in the bilges.   Thus water is pumped from these compartments, through the pump, and is discharged through a non-return valve on the ship's side, above the waterline.

The same suction pipes to the tanks may also be used for filling the tanks from the sea.   The pump draws the water from the sea suction valve, which is in the shell at the bottom of the ship, adjacent to the pump.   The sea-valve is, of course, well below the waterline, the farther below the better the head of water.   The water then goes through the pump and through a cross-connection valve, via the suction line, into the tanks.   If only one or two tanks are to be filled for ballast, then only the valves on the suction line to those particular tanks are opened, the valves on the lines to the remaining tanks being kept closed.   So much for the bilge and ballast pump.

The next pump which concerns us is the general service pump, fitted on the starboard side of the ship in the engine room, in this particular case.   Adjacent to the pump, connected to the suction side of the pump is a six-valve chest, which controls the various pipe leads for which the general service pump is used.   Firstly,

Fig. 15—Typical Pumping Arrangements of a Cargo Steamer.

there is a $2\frac{1}{2}''$ direct suction from a strum box in the engine room itself.   Another branch is a $1\frac{1}{2}''$ suction from the 100-gallon sanitary tank aft, while still another is cross-connected to the fresh water pump at the after end of the engine room.   This latter pipe enables either or both of the two-feed or fresh-water tanks to be pumped out either by the fresh-water pump or alternatively by the general service pump.   A fourth branch is cross-connected with the main engine pump and hot well, enabling either the main engine pumps or the general service pump to do all the work of the other.   A fifth branch is to the sea suction valve for use with the fire service, and the sixth and final branch is led to another valve chest consisting of four valves on the port side, which will be dealt with later.   On the discharge side of the pump is a two-valve chest, one valve connecting to a $2\frac{1}{2}''$ discharge overboard, and the other connecting to the $2''$ fire-main led up to a valve and hose connection on the deck.   The discharge from the pump is fitted with a non-return valve on the ship's side, above the waterline.

To return to the four-valve chest on the port side.   This is connected both to the main engine pumps and to the general service pump, so here again the suctions emanating from this chest may be pumped out by either pump.   One of these suctions leads to a strum box at the fore end of the tunnel, another to a strum box in the boiler room, the third to a strum box at the after-end of the cargo hold, and the fourth to the hold space forward.   Thus, any or each of these spaces may be pumped out by either the main service pumps or the general service pump.

This completes the pumping and flooding arrangements for the ship illustrated, as far as the actual piping is concerned.   In addition to the system, however, air pipes and sounding tubes are fitted to the various compartments.   Air pipes are fitted to the deck overhead of the compartment concerned, usually consisting of a pipe with a swan neck.   These are fitted to allow the air to escape in the event of the compartment being flooded with water. If air pipes were not fitted, as the water rose in the compartment, the air would be compressed under the deck, causing serious damage to the plating.

Sounding tubes are fitted from a deck-plate on the weather deck down to the bilges, for sounding the depth of water in the compartment.

PUMPING ARRANGEMENT OF A SMALL SOUTH SEAS TRADING VESSEL.

The pumping arrangement, illustrated in Fig. 16, is for a 100-ft. South Seas trading vessel, and it will be seen at a glance that the system is far less complicated than the previous example.

Commencing with the bilge pump in the motor room amidships,
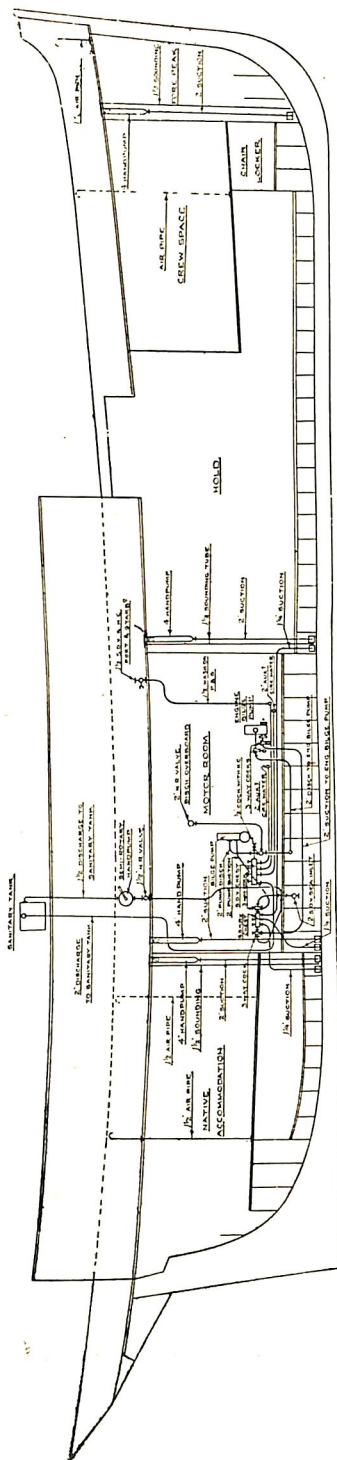
Fig. 16—100-ft. South Seas Trading Vessel—Pumping Arrangements.

let us follow the system through the ship. In the first place, this is cross-connected to the engine bilge pump at the fore end of the motor room, thus enabling either pump to do the work of the other in emergency. Both of these pumps are power-operated.

Taking the suction side of the pump, we find a screw-down non-return valve chest at the after-end of the motor room. On each side of this is a three-way cock, one branch from the forward cock being taken to the bilge pump, and one from the after cock being taken to the engine bilge pump. The second branch of the forward three-way cock is led to a sea inlet valve on the ship's bottom, the third branch being fitted to the valve chest.

With regard to the after three-way cock, the second branch is cross-connected by means of a four-way piece or cross to the sea inlet valve, and also is led up to supply the sanitary tank on the deck. The third branch of this cock is fitted to the after-end of the valve chest. The chest is composed of three valves, one controlling the suction from the hold forward, the second controlling the suction from the motor room, and the third that from under the natives' accommodation aft. Strum boxes are fitted to the suctions.

Taking the delivery side of the pump, we see a four-valve, screw-down valve chest. This has two branches to the auxiliary circulating water system ; one branch is led to two wash deck valves, fitted one on the port side and one on the starboard side of the ship, whilst the fourth branch is a 2″ discharge from the bilge pump, for filling the sanitary tank.

On the fore end of the delivery valve chest is a four-way piece, one branch being bolted to the chest. The second branch leads direct to the bilge pump, and third to a cock fitted with a hose connection, whilst the fourth branch is led to a three-way cock.

This cock in turn has one branch to a 2″ non-return lift valve on the ship's side just above the waterline, which constitutes the pump discharge overboard, while the other branch is led to the engine bilge pump.

Now let us see how this system works. If the engine bilge pump is being used, then the ordinary bilge pump is shut off altogether. For pumping out a compartment, the necessary suction valve is opened, water is drawn through the cock on the aft end of the suction chest, down the branch leading to the engine bilge pump. It is then ejected through the pipe leading to the discharge overboard, the three-way cock on this pipe being opened to suit. If the ordinary bilge pump is used, then the process is similar, except that the water is drawn through the three-way cock on the fore end of the suction valve chest, through the bilge pump.

If water is required for wash deck service and the ordinary bilge pump is used, then it is drawn through the sea inlet valve

to the three-way cock at the fore end of the suction chest, up to the pump.   It is then pumped down to the delivery chest and through the required valve, to whichever of the two wash deck valves it is required to use.   Both may be used if necessary.

If the engine bilge pump is used the arrangement is slightly more complicated.   The water is drawn through the sea inlet valve up to the three-way cock on the after-end of the suction chest, and from there it is drawn to the pump.   The pump discharges it up through the three-way cock just forward of the delivery valve chest, into the chest and through the required valve up to the wash deck valves.

Similarly, the sanitary tank may be filled from either pump, water being drawn through the sea inlet valve to whichever pump is being used, discharging from the pump, through the necessary valve in the delivery chest and thence to the sanitary tank.

The sanitary tank may also be filled direct through the sea inlet valve, by means of a semi-rotary hand-pump, which has a 1½″ non-return valve fitted just beneath, to prevent water running back down the pipe.

In addition to the power-operated pumping arrangements, this ship is equipped with 4″ hand-pumps, one fitted in each compartment.   The hand-pumps are fitted with 2″ suction pipes, led to strum boxes in the bilges and discharged through the ship's side above the waterline.   Each compartment is fitted with a sounding pipe and an air escape pipe.   The sounding pipes are fitted adjacent to the hand-pump deckplates on the weather deck.

PUMPING ARRANGEMENTS OF A PADDLE STEAMER.

Fig. 17 gives a typical arrangement for the pumping system of a paddle steamer.

It will be seen that in this instance pumping may be carried out by any of three pumps, a main engine pump, a donkey pump, and a Downton pump.   The sea inlet valve at the after-end of the machinery space will serve all three pumps.

Taking the suction system first, we find that there are three main suction valve chests, one under each pump.   Under the donkey pump is a three-valve chest, under the main engine pump a four-valve chest, whilst beneath the Downton pump is another three-valve chest.

The suction valve chest under the donkey pump has one branch from the sea suction, one from a strum box in the engine room, and one connecting it to the four-valve chest under the main engine pump.   The three-valve chest is then connected direct to the donkey pump.   The four-valve chest has two branches, each to a strum box in the engine room, and two branches, each
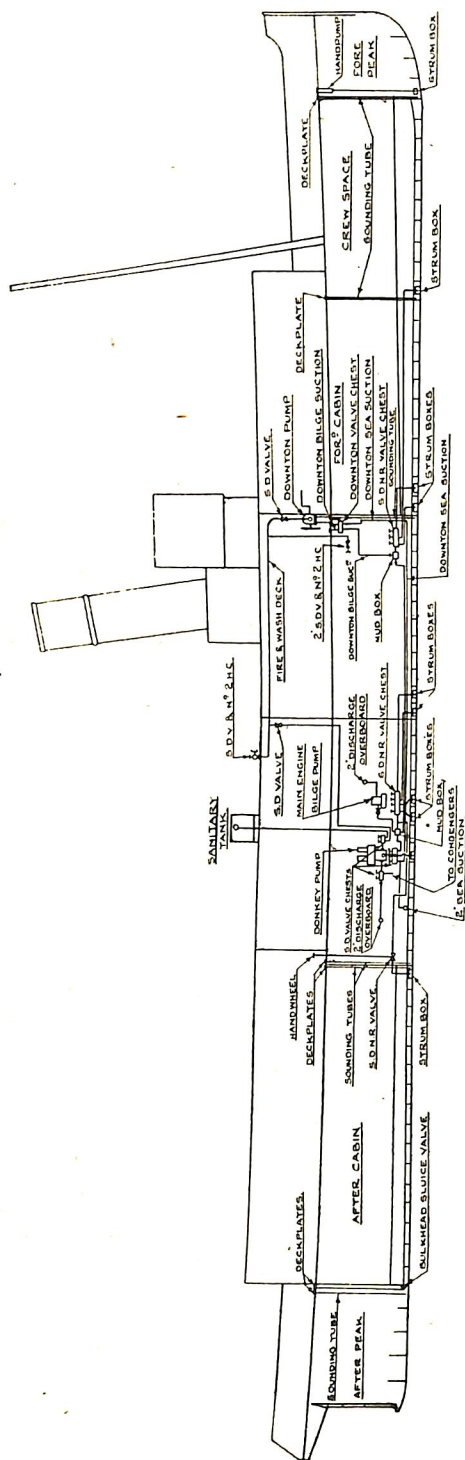
Fig. 17—Typical Pumping Arrangements of a Paddle Steamer.

to a strum box in the boiler room. The forward three-valve chest has branches leading to strum boxes in the forward compartments.

Between the after suction valve chest and the chest underneath the main engine pump is fitted a mud box. This is a casting containing a strainer plate, to prevent mud being drawn through the pipes and clogging the pumps. A branch from this is taken to the main engine pump and fitted with a screw-down valve, whilst another branch is led forward constituting the bilge suction line to the fore end.

A mud box is also fitted on the aft side of the forward valve chest, with a branch up to a valve chest under the Downton pump. This branch is the Downton bilge suction.

The chest is a two-valve chest, being fitted under the deck, and operated through two deck-plates on the deck. The other valve in the chest is for the Downton sea suction, which is led from a branch off the main sea suction.

Between the after mud box and the four-valve suction chest a branch is taken off leading to a strum box in the after compartment. This branch is controlled by a screw-down non-return valve, geared to a hand-wheel on the deck above.

With regard to the pump delivery system, first we see there are two valve chests fitted, one on the forward side and one on the after side of the donkey pump, and connected to it. Each chest is composed of two valves, with the branches on the forward chest leading, one as a supply to the sanitary tank on the top deck, and one being led into the Downton pump supply to the fire and wash deck valves on the weather deck. The after chest has one branch leading to the condensers, for circulating water, and one branch leading to the discharge overboard.

The main engine pump has simply a discharge overboard on the delivery side.

The Downton pump has a hose connection on the delivery side for discharging overboard by means of a hose, and also a branch for fire and wash deck services, having screw-down valves and hose connections fitted on the weather deck and in the boiler room.

In addition to the foregoing power pumps, a deck hand bilge pump is fitted forward for pumping out the fore peak. The suction is led from a strum box in the bilges, while the discharge is led through the ship's side above the waterline, the deckplate for operating being on the deck above. The after peak is not pumped out, but has a bulkhead sluice valve fitted to the forward bulkhead, as low down as possible. This is geared to a deckplate on the deck above and when the valve is opened bilge water drains into the next compartment forward, where it is dealt with by the power-operated suction in that compartment. Each compartment

is fitted with a sounding tube, and (although not shown in the illustration) an air pipe of the swan-neck type, fitted close to the bulwarks at the ship's side. From the descriptions given, it should now be possible for the reader to trace out the various ways in which this particular ship may be pumped and flooded, and we will now pass on to the final representative example.

Having taken cargo steamer, trading yacht and paddle steamer, we will now take an ordinary pleasure yacht.

PIPING ARRANGEMENT OF A PLEASURE YACHT.

In this arrangement there are four power-operated pumps, all fitted in the engine room (see Fig. 18).

Two of these are the main engine pumps, one to each engine, the third is the bilge pump, and the fourth is the fresh-water pump.

As in previous examples, the main engine pumps and the bilge pumps are cross-connected, and in this case have the same sea suction and discharge overboard. All three pumps are connected to a four-valve suction chest on the port side, at the after-end of the engine room. Two branches from this chest are suctions from the after watertight compartments, one a suction from the baggage store, and one a supply to the sanitary tank in the engine room.

A four-valve suction chest is fitted at the fore end of the engine room on the starboard side, with a suction pipe leading into the cross connection between the main engine pumps and the bilge pump. The four branches from this chest lead, two to strum boxes in the engine room, and two to strum boxes in the forward compartments.

It is thus possible to pump out the after compartments, fill the sanitary tanks, or pump out the forward compartments and the engine room, by means of either the main engine pumps or the bilge pump in the engine room.

The fresh-water pump is fitted to deal exclusively with the fresh-water tanks, and is connected to a three-valve suction chest at the fore end of the engine room on the starboard side. One branch from this chest is led to a strainer in the after fresh-water tank, and one to each of the two forward fresh-water tanks.

Fresh water may be pumped from any of these tanks, through the fresh-water pump, and discharged to a fresh-water gravity tank on the deck over, from which it is supplied to the fresh-water system.

The fire and wash deck service has been omitted in the description, because in this particular instance a separate system was fitted for this purpose and space will not allow of a detailed description of this.

In addition to the above power pumps, a 1″ semi-rotary hand-pump is fitted at the after end of the engine room, with 1″ suctions
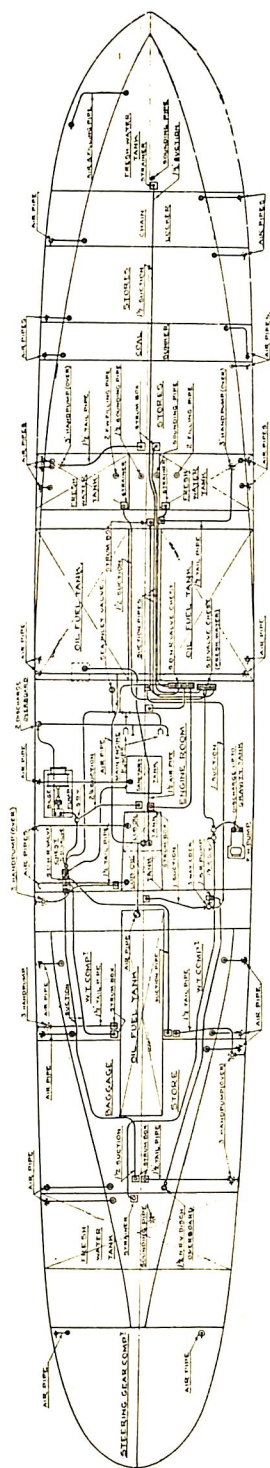
Fig. 18—Typical Pumping Arrangements of a Pleasure Yacht.

fitted to both the forward and after ends of the engine room, both suctions being controlled by a three-way cock. The discharge pipe is led aft to a 1½" non-return valve in the baggage store.

In addition to the pumps in the engine room, 3" hand pumps are fitted in the more important of the hold compartments, for pumping out the bilges by hand. These are fitted with a 1½" tail pipe to a strum box in the bilges, and discharge overboard underneath the deck. Air pipes and sounding pipes are fitted as shown.

GENERAL NOTES ON PIPE ARRANGEMENTS.

In the arrangements described, all fittings and pipes are shown diagrammatically for the sake of clarity, but some firms make a practice of drawing the arrangements on a large scale, giving the exact position of each pipe and fitting as it is required to be arranged at the ship. This method undoubtedly saves time in the workshops, as the pipes may be bent from the drawing without checking distances, etc., from ship.

This system, however, works well in the engine and boiler rooms, where there is a place for everything and everything is in its place, but is not generally used outside the machinery spaces. This is due to the fact that there are so many different fittings which can only be arranged satisfactorily by deciding their final positions from the ship, that it is not worth the time and trouble to draw a plan of the exact positions of the pipes outside the machinery spaces.

Although not shown, it is taken for granted that bulkhead and deck pieces will be fitted wherever pipes pierce watertight bulkheads and decks. Pipes should always pierce watertight bulkheads as high as possible above the waterline. Flanges should be allowed for at the rate of two to every ten or twelve feet of pipe, and also wherever a pipe is connected to a flanged fitting.

When ordering pipes and fittings from drawings, always allow 10% for wastage and for unforeseen extras. This of, course, applies only to fittings ordered in bulk, such as tee pieces, flanges, elbows, sockets and backnuts, etc.

When designing a pumping arrangement, always read the specification carefully to make sure that all requirements have been embodied.

The suctions and fire-mains so far described have been comparatively simple ones, but some are a little more complicated. On the larger type of ship, main suction and fire-main lines are usually taken from the pump and led under the deck overhead, forward and aft throughout the ship. Branches are taken from these main lines and led to the various compartments, being fitted with operating valves in accessible positions. In this way any

compartment may be pumped or flooded once the pump is started, and controlled from a point adjacent to that compartment. This is because, if the pipes to the compartments were controlled from valve chests in the machinery spaces, it would be impossible to run the length of the ship to discover how the work was proceeding.

CLASSIFICATION RULES FOR PUMPING AND FLOODING.

If the vessel under construction is required to pass Lloyds' or Board of Trade Rules, then these rules should be studied thoroughly before designing the pumping arrangements of the ship.

Lloyds' Rules, for instance, call for the diameters of bilge suction pipes to be to the following formulae :—

$$\sqrt{\frac{L \ (B + D)}{2,500}} + 1 \text{ for mainline.}$$

and

$$\sqrt{\frac{C \ (B + D)}{1,500}} + 1 \text{ for branches.}$$

Where

L is the length from fore side of stem to aft part of sternpost on load water line, or over cruiser stern in cruiser stern types.

B is the moulded breadth.

D is depth from top of keel to top of beam at side of uppermost continuous deck.

C is the length of compartment.

All dimensions to be in feet.

No main suction should be less than 2″ bore, and no branch less than 2″ bore or more than 4″.

Thus many of the requirements for the pumping system are decided before the design is commenced.

CALCULATION FOR FLOODING A MAGAZINE.

When a magazine or similar compartment containing highly inflammable material is fitted on a ship, special arrangements are made to flood the compartment in the event of fire breaking out.

The method in general use is to have a seacock on the shell below the waterline, connected by a pipe to a flood valve in the compartment required to be flooded. Both seacock and flood valve are geared to handwheels on the weather deck, from which position they may be quickly opened in an emergency.

Irrespective of the size of the compartment, it is necessary that the flooding be completed in a minimum possible time, usually

taken as fifteen to twenty minutes at a maximum.   It is therefore necessary to calculate the size of valve required to flood the compartment within this time.   This, if a strictly accurate result were required, would be a very complicated calculation, involving as it does a constantly changing head of water, in addition to friction in the pipe and valve, depending on number of bends and method of construction.

Fortunately, either of two simple methods may be used to give us an answer to within half-an-inch, and if the flood valve and seacock are ordered to a bore to the nearest half-inch above that calculated, then the result should be satisfactory.

It is proposed to give both methods, showing that in spite of slight differences, the results will be similar enough to meet our requirements.

CALCULATION BY METHOD 1.

The calculation will be in two parts :—

(a) To calculate the time taken to flood magazine up to the bottom of the flood pipe, owing to a constant head of water due to the water level at which the ship floats.

(b) To calculate the time taken to flood the magazine from bottom of flood pipe to roof of magazine (or to the load water line, whichever is the lower).

(It is obvious that if the roof of the magazine is higher than the draught of the ship, then the magazine will only flood up to the level of the ship's draught, due to the fact that water will always find its own level).

If the magazine is fitted with a flat, either wood or steel, which is usually the case, then the flat may be assumed watertight for the time of flooding.   Therefore the volume below the flat may be deducted.   Also, all stowages must be deducted.

Below is given a typical example, the actual capacity, head of water, length and diameter of flood pipe will, of course, vary with each individual case.

(a) Cubic capacity to bottom of flood pipe = 333 cub. ft.
Deduction for stowages up to bottom
of flood pipe,   =   33 cub. ft.
∴   Volume floodable up to flood pipe   = 300 cub. ft.

Taking a 6″ bore flood pipe as a basis for calculation, and taking a constant head of 3·375 feet above the level of the flood pipe in this particular instance :—

Then velocity of inflow of water $= C \times 8\sqrt{h}$,

where $h =$ head of water and C is a coefficient for different diameters of pipe in accordance with the following table :—

Length Dia.	C.	Length Dia.	C.	Length Dia.	C.
1	·61	13	·73	49	·60
2	·82	25	·67	60	·56
4	·76	37	·62	100	·48

Taking $\dfrac{L}{D}$ as 13, then C is ·73 for this case.

∴   Velocity $= ·73 \times 8\sqrt{3·375} = 10·73$ ft./sec.

Time to flood to bottom of flood pipe, taking 6″ diameter flood valve as a trial size :—

Area of 6″ bore pipe $= 28·274$ sq. ins.

$$= \frac{300 \times 144}{28·274 \times 60 \times 10·73} = 2·373 \text{ mins.}$$

(b)   Total cubic capacity of compartment $= 1,558$ cub. ft.
Deducting for volume floodable below
   pipe $= 1,558 - 300$ $= 1,258$ cub. ft.
Stowage $= \ \ 140$ cub. ft.
Deducting for stowage $= 1,258 - 140$ $= 1,118$ cub. ft.
   floodable above flood pipe.

$\sqrt{h} = 1·837$ ft. for second part of calculation in the example we are taking, as $h = 3·375$ as above.

But average h for the second part of calculation will naturally decrease, as we are flooding up to top of magazine.

∴   Mean head during flooding $= (2/3\sqrt{h})^2 = (2/3 \times 1·837)^2 = 1·5$
      Velocity of inflow $= C \times 8\sqrt{h}$ again,

Which equals $·73 \times 8\sqrt{1·5} = 7·16$ ft./sec.

∴   Time to flood magazine above flood pipe

$$= \frac{1118 \times 144}{28·274 \times 60 \times 7·16} = 13·25 \text{ mins.}$$

∴   Total time to flood magazine $= 13·25 + 2·373 = 15·623$ mins., which is a reasonable time, therefore a 6″ bore flood pipe is suitable for flooding magazine.   If the result had been more than twenty minutes, then a larger bore of valve would have been necessary ; if less than twenty minutes, then in the interests of economy a

smaller bore valve could be substituted. If a reasonable result is not obtained with the first bore of valve tried, other valve sizes should be substituted until a reasonable figure is obtained.

CALCULATION BY METHOD 2.

If V = volume of compartment in cubic feet.
      A = area of flood pipe in square feet.
      C = constant, as in table on page 51.
      $h_1 \, h_2$ = initial and final heads of water.

Then, for flooding a magazine whose flood pipe is part way down the side of compartment, calculate separately (as in Method 1) the volumes above and below the level of the flood pipe.

For the volume above flood pipe use the formula :

$$\left(\frac{V}{240 \; A \; (\sqrt{h_1} + \sqrt{h_2}) \; C} \right)$$

For the volume below flood pipe, use formula :

$$\frac{V}{480 \; AC \; \sqrt{h}}$$

where h is the head of water to centre of flood pipe. The results of these calculations, when added together, will give the time in minutes required to flood the magazine.

Here again, if the result is between fifteen to twenty minutes, the bore of the flood pipe is satisfactory, but if more, then a larger bore of pipe should be substituted.

Taking the same figures as for Method 1 :

Time to flood up to centre of flood pipe =

$$\frac{300 \times 144}{480 \times 28 \cdot 274 \times \cdot 73 \sqrt{3 \cdot 375}} = 2 \cdot 374 \text{ mins.}$$

Time to flood above flood pipe

$$= \frac{1118 \times 144}{240 \times 28 \cdot 274 \times \cdot 73 \sqrt{3 \cdot 375}} = 17 \cdot 69 \text{ mins.}$$

3·375 ft. being the initial head of water and there being no final head, as the water line is on a level with the top of the magazine.

Total time by this method = $17 \cdot 69 + 2 \cdot 374 = 20 \cdot 064$ mins., which is just over four minutes more than the time calculated by the first method. The difference is not so great between the results from the two formulae when the waterline of the ship is above the top of the magazine, but even in the example shown, the difference is not so great as to alter the size of valve required.

Both methods, as has been mentioned before, are approximate, but are quite accurate enough for all normal purposes. Either method may be used, but Method 2 is a slightly quicker way of arriving at the required result.

CONCLUSION.

In the foregoing pages an attempt has been made to outline the various fittings, and arrangements of fittings, employed in the pumping and flooding of ships. Much of the subject matter will appear simple to the initiated, but it is hoped that the apprentice and junior draughtsman without previous knowledge of the subject may find in this pamphlet at least an idea of the first principles from which he may obtain more extensive knowledge on the subject.

In a pamphlet of this size, it is possible to give only a brief outline of the subject, so the author must be excused if some subjects are not dealt with as extensively as others.

In conclusion, may I thank the firm of J. SAMUEL WHITE & COMPANY. Ltd., of Cowes, for the help which I have always received on this subject, while I have been in their employ.

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2. Deflection of Shafts and Beams   } Connected.
3. Deflection of Shafts and Beams (Instruction Sheet) }
4. Steam Radiation Heating Chart.
5. Horse-Power of Leather Belts, etc.
6. Automobile Brakes (Axle Brakes)   } Connected.
7. Automobile Brakes (Transmission Brakes) }
8. Capacities of Bucket Elevators.
9. Valley Angle Chart for Hoppers and Chutes.
10. Shafts up to $5\frac{1}{2}$-in. diameter, subjected to Twisting and Combined Bending and Twisting.
11. Shafts, $5\frac{3}{4}$ to 26 inch diameter, subjected to Twisting and Combined Bending and Twisting.
12. Ship Derrick Booms.
13. Spiral Springs (Diameter of Rd. or Sq. Wire).
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28. $\frac{7}{8}''$,,   ,,   ,,   (40   ,,   ).
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30. Moments of Inertia of Built-up Sections (Tables)   } Connected
31. Moments of Inertia of Built-up Sections (Instructions) } and Examples).
32. Reinforced Concrete Slabs (Line Chart)   } Connected
33. Reinforced Concrete Slabs (Instructions and Examples) }
34. Capacity and Speed Chart for Troughed Band Conveyors.
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